INHERITANCE OF EARLINESS IN BARLEY

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T H E U N I V E R S I T Y O F A L B E R T A

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The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance, a thesis entitled, "Inheritance of Earliness in Barley", submitted by Gilbert I. Paul, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

A field project involving the study of F_1, F_2 and F_3 hybrids from 16 crosses between barley varieties ranging in dates of maturity from early to late, was carried out during the summer of 1951. The F_1 and F_2 were studied during the previous year and are included in the analysis to provide a link between the F_2 in 1950 and the F_3 in 1951. The latter generation is the basis of the genetic analysis.

Seven of the crosses have been analyzed. The increased variance in a segregating line over that of a non-segregating, or pure line is used as a basis for classifying the F_3 lines into two classes, segregating and non-segregating. The ratio of the classes, so determined, is an indication of the number of genes segregating for earliness and suggests a further classification based on the means of the F_3 lines. A final check on the validity of the phenotypic classification is the distribution of homozygotes within the classes.

The conclusions reached take into consideration:

(a) behaviour in F_1 and F_2 generations,

(b) parental recovery in F_2, (the distribution is simulated by the F_3 means)

(c) transgressive segregation,

(d) ratio of segregating to non-segregating F_3 lines,

(e) proportion of homozygous individuals in each phenotypic class, and

(f) the origin of the parent lines.

It was found that the varieties of barley studied differed in their gene make-up at two loci. However, the possibility of one major gene difference, conditioned by minor genes, is not excluded.

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INTRODUCTION

The phenotypic expression of a quantitative character such as earliness may be considered as the sum of a genetic effect, a deviation attributable to environment and the interaction between the genotype and environment involved. Although environmental effects are studied herein only to the extent to which they may be controlled, or eliminated, it is important to examine the many ways in which the environment affects the earliness characteristic in barley.

Bell (2) stressed the relationship between physiology, heredity and environment in the expression of earliness. The time at which a particular cereal variety comes into head is the manifestation of a complex series of physiological processes within the plant. He found the light requirement

to be an exceedingly important factor in determining earliness, for example, a plant which is early in one area may react quite differently in another area where the light intensity and duration differed.

Other workers, as reported by Smith, (11) found that temperature, nitrogen content of the soil, sand content of the soil, and special concentrations of auxins and coumarin were significant influences on time of maturity in barley.

On the genetical side, workers, as reviewed by Smith (11), have found the expression of earliness to be dependent on from one to many genes. Griffee (5) reports a single gene pair responsible for earliness and that the gene for earliness is dominant. Johnston and Aamodt (9,10) studied the F_3 generation from a cross between an early and a late variety and considered that earliness was best explained on the basis of polymeric genes. They found that time of heading is so influenced by environmental factors that data pertaining to individual plants are of no great significance, and also that it is impractical to use parental distributions as a measure of homozygosity. Their conclusions were that earliness was dependent on two or more gene pairs and that transgressive segregation for both earliness and lateness was clear.

Wilson (13) conducted one of the first genetic studies of early maturity and indicated that earliness was recessive to lateness.

Bell (2) postulated that, within a pure line, normally developed plants will occupy a period of from four to five days to accomplish over-all ear emergence in a plot of 200 to 250 plants. He found that difference in time of seeding varies from year to year and that seeding F_1, F_2 and F_3 generations in successive years was much less valuable than seeding all generations under study within the same year and at the same date. The F_1 generation in his study inclined toward the later parent and the F_2 reacted oppositely. Transgressive segregation appeared in some crosses.

From the above review it is quite apparent that environment and genetic constitution determine the earliness of a plant almost equally. The genotype determines the capability of a plant to be early and the environment determines whether and to what extent this capability will be expressed.

These two main influences may be difficult to separate, especially when the genetic variance is affected by (a) epistasis (i.e., all types of interactions among non-allelic genes), (b) varying degrees of dominance, and (c) the presence of linked genes.

OBJECTIVES

The object of this study is to determine the mode of inheritance of the earliness characteristic in barley. Mode of inheritance, here, includes questions of (a) the number of genes that have an effect on the phenotype, (b) whether the genes common to a particular variety are increasing allelomorphs (AABBCC...), or decreasing allelomorphs (aabbcc...), and (c) whether the genes for earliness are dominant, partially dominant, or recessive to lateness.

Work leading up to the final analysis was done chiefly on F_1 and F_2 generations of plants from early x early, early x late and late x late crosses. The purpose of the present study is to carry out a more critical analysis on the F_3 generation of plants. F_1 and F_2 generations were included in the project to provide a link between the F_3 of 1951 and the F_2 generation of 1950. However, the main emphasis will be placed on F_3 data and their analysis.

MATERIALS AND METHODS

The summer of 1951 was an unusually good season for carrying out the study of the inheritance of earliness. At no time was there a lack of moisture, nor did the temperature fluctuate appreciably during the period of vegetative growth and of heading. All of the material was seeded within a two-day period on a level piece of land approximately square in shape. The above factors serve to lessen the degree of variation introduced into the F_3 hybrid lines. In addition, special devices, such as the growing of an O.A.C. 21 check uniformly dispersed throughout the test and the growing of a parental variety for every five hybrid lines, were used to aid in controlling the variation due to non-heritable sources.

F_3 progeny, each associated with a particular phenotype (days to heading) in the F_2 parent, were seeded in individual 13-foot rows, one foot apart, on a specially selected plot of land. To facilitate handling of the material the project was conveniently divided into five replicates. The first three were seeded on essentially the same day and included practically all of the F_3 hybrid material. Replicate four is of special interest, much smaller in number, and

will not be treated in the present analysis. Replicate five was seeded three weeks later than the preceding four and contains, in addition to the F_3 hybrid lines, F_2 generations from the same crosses, and F_1 generations from three of the crosses. The replicates are so-called for want of a better name. They have in common the same crosses but not the same number within each cross.

Sixteen crosses between varieties ranging in time of maturity from early to late were seeded. The crosses were made up of the following combinations: early x early, (2 crosses) mid-early x early, (1 cross) mid-early x mid-early, (1 cross) mid-early x late, (1 cross) late x mid-early, (2 crosses) early x late, (3 crosses) late x early, (3 crosses) and late x late (3 crosses). Of these sixteen crosses, the results from seven will be discussed in this paper. The composition of each cross studied is summarized in Table I.

Table I

Composition of Barley Crosses Studied

No. of Cross	Type of Cross	Composition of Cross	Generations Studied
1	early x early	Atsel x Tulare	F_1, F_2, F_3
2	early x late	Atsel x Bonneville	F_1, F_2, F_3
3	early x late	Atsel x Frontier	F_2, F_3
4	late x early	Montcalm x Atsel	F_2, F_3
5	late x early	Montcalm x Beecher	F_2, F_3
6	late x early	Montcalm x Tulare	F_2, F_3
7	late x late	Frontier x Bonneville	F_1, F_2, F_3

Following emergence, the plants were uniformly thinned to three inches between plants to facilitate individual plant study.

Heading notes were taken each day from the time the first plant headed until the heading period was completed. In all, daily records on heading were taken on about 85,000 plants. The criterion used to classify a plant as being headed was the extrusion of the top floret above the flag leaf. Days to heading was taken to be the measure of the earliness of a plant. Previous workers (2, 9, 10) have found the date of ear extrusion to be a more reliable measure

of earliness than the actual date of maturity of the plant. Not only did the date of extrusion fluctuate less readily, but also the plant was less susceptible to diseases and pests during the period immediately preceding heading than during the period between heading and ripening. In addition, it is much easier to determine the time of heading than the time of maturity; which is an important consideration when studying a large number of plants.

All crosses under study are between varieties of barley within the genus Hordeum vulgare L.

Atsel, C.I. 6250 [1], originated as a plant selection made from a commercial lot of Atlas barley at Davis, California, in 1933. (1) Atlas, C.I. 4118, in turn is a pure line selection made from Coast, C. I. 6115, the original barley introduced by the Spanish settlers. The more remote origin of Coast was postulated to be North African.

Beecher, C.I. 6566, is derived from the cross Atlas x Vaughn. Vaughn, C.I. 1367, of hybrid origin, came from the cross Lion x Club Mariout. Lion, C.I. 923, is an introduction from Southern Russia, and Club Mariout, C.I. 261, was introduced from the irrigated sections of Lower Egypt in 1903.

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[1] Cereal Investigation number (U. S. Dept. of Agriculture).

Montcalm, C.I. 7149, originated from the cross (Michigan 31604 x Common Six-Rowed 4307 M.C. [2]) x Mandscheuri 1807 M.C. The Michigan 31604 parent is similar to Lion, while the other two parents are of the Manchuria type.

Frontier, C.I. 7155, is a selection from one of a large number of crosses made by Harlan et al. (7). The selection came from a portion of the material where all crosses were bulked, hence the exact parentage is unknown.

Bonneville, C.I. 7248, is derived from the cross Colorado 3063 x Winter Club (7). Colorado 3063 in turn came from the cross Coast x Lion. According to Harlan and Martini, (6) the history of Winter Club, C.I. 592, is unknown.

Little is known about the variety Tulare, other than that, under Californian conditions, the variety was found to be two or three days earlier than Atsel. Under Edmonton conditions, Atsel is the earlier variety.

The arithmetic means and variances were calculated for each row of material, including parent varieties, F_1 progeny, F_2 progeny and F_3 progeny lines. The mean days to heading was considered less subject to environmental influences than the days to heading of a single plant and therefore the mean of each F_3 line is used to identify the phenotype of the F_2 parent from which it was derived. All of the F_3 means from one cross taken as a whole simulate the

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[2] Macdonald College number

F_2 distribution, the distribution in which segregation begins.

The variance is used as a measure of the variability within each row. In parental rows the variance consists of a component due to non-heritable sources only, since parent varieties are considered pure lines in which no segregation for major characteristics occurs. The F_1 resulting from a cross between two pure line parents is genetically stable, in that, the genotypes of the plants are all alike, and therefore its variance consists of a non-heritable component only. In the F_2, segregation of genes occurs, and the F_2 distributions contain an heritable component of variation in addition to the non-heritable portion common to non-segregating lines. The increased variance of the F_2 over the genetically stable lines is a function of the number of gene differences between the two parents (neglecting the effect of linked genes, epistasis and dominance).

Some of the genotypes in the F_2, depending on the size of the population, will be like the parent genotypes. The number of parental recoveries is an indication of the number of loci involved in expressing the character, earliness, in a certain population size. If earliness is a dominant character, there will be pronounced positive skewness, and if earliness is recessive, a negatively skewed distribution will result. With complete absence of dominance the F_2

distribution will be symmetrical.

The test of the genotype is in its progeny. If in the F_2 there occur genotypes like each parent, then in the F_3 generation there will be lines phenotypically like each parent and with equal variance. The ratio of segregating to non-segregating F_3 lines is an indication of the number of genes in which the parent varieties differ.

An average variance of the parental varieties used as checks was calculated to assess the separate variances of the F_3 lines and thereby arrive at a "first estimate" of the number of homozygous lines in the F_3 generation.

In a monohybrid cross, with dominance absent the theoretical ratio of segregating to non-segregating lines is 1:1. The phenotypes are divided into 3 classes, 1 AA : 2 Aa : 1 aa. The non-segregating lines being distributed in the extreme classes. In a dihybrid cross the phenotypic classes are as follows:

Ratio	1	:	4	:	6	:	4	:	1
	(1) AABB		(2) AaBB		(4) AaBb		(2) Aabb		(1) aabb
Genotype			(2) AABb		(1) AAbb		(2) aaBb		
					(1) aaBB				

Here the ratio of segregating to non-segregating F_3 lines is 3:1. The non-segregating F_3 lines are distributed in the first, third and fifth classes in a ratio of 1:2:1.

In a trihybrid the phenotypic classes are seven in number with the ratio being 7:1, (segregating to non-segregating) and the distribution of the non-segregating lines is according to a 1:3:3:1 ratio in the first, third, fifth and seventh classes.

The means of the F_3 lines were used as a basis for classifying the data into the number of phenotypic classes. The ratio of segregating to non-segregating lines was an indication of the number of classes to be used, and the final test was the distribution of the homozygotes.

Snedecor's F test (12) was used to test the homogeneity of the variances of the F_3 lines and the variances of the parental check rows. The denominator in each case was the composite variance of the parental rows and the numerator was the variance of each F_3 line.

A ratio giving an F value significantly greater than one was considered to be significant and the particular variances that were homogeneous were assumed to be from non-segregating F_3 lines. Thus, ratios of segregating to non-segregating lines were obtained for each cross. The ratios were tested for goodness of fit to hypothesized genetical ratios by the Chi-Square test for goodness of fit (12).

Table II

	Days to heading of F_1 and F_2 hybrids and parental varieties																			Mean	Variance	N
	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59			
Atsel	1	3	5	2																42.7	0.818	11
Tulare		1	22	18	3	4														43.7	0.883	48
F_1				1	5	5	1													45.5	0.636	12
					2	5	3	3												46.5	1.108	13
					1	1	2	2												46.8	1.380	6
F_2			5	5	3	1	2	6	17	8	3	7	3	1	1					48.6	9.183	62
		1	2	6	3	2	12	7	11	7	3		2	1						47.7	6.733	57
	1	2	1	2	1	1	7	4	6	8	5	4	5	4	2	2	1			49.7	13.691	56
F_3 means			2	2	3	4	1															

Table II (continued)

Days to heading of F_1 and F_2 hybrids and parental varieties																														
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	Mean	Variance	N
Atsel	6	9	7	2		1																					43.4	1.407	25
Bonneville																	7	23	13	9	19	2	5	1	2		60.7	3.704	81
F_1									1		3	3	2														52.6	1.525	9
								1	4		6	6	3														52.1	2.258	20
											2	3	1														52.8	0.560	6
F_2			1			2	1	7	1	3	3	4	8	10	3	6	4	2					2	1			54.1	17.173	58
			1		3	1	3	5	8	6	5	12	11	9	6	7	3										52.7	10.151	80
F_3 means											1	1																	
Atsel	1	14	5	1	1	1		1																			43.8	2.433	24
Frontier															6	18	31	7	9	2	4	3	1				58.5	3.252	81
F_2						1				10	5	7	9	8	10	5	6		1	3	1	2	1				55.1	11.475	69
						1		2	2	4	2	7	6	7	10	3	3	1	1	1	3		1	1	2	1	55.7	19.502	58
					2	2	1	5	3	2	5	7	8	10	13	1	3	5									53.7	10.879	67
					2			3	5	5	6	10	12	14	8	5	4	4	2								54.1	8.718	80
F_3 means							1	2		3	1	1			1									1					

Table II (continued)

Days to heading of F_1 and F_2 hybrids and parental varieties																								
	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	Mean	Variance	N
Montcalm															10	23	22	11	4	1			54.7	1.326	71
Atsel				1	9	3		1															43.4	0.862	14
F_2						3	2	6	6	1	2	4	5	4	4	5	7	15	2	4	3	1	52.4	19.589	74
		1		1	2		3	2	1	2	8	3	8	5	4	9	2	7	5	1			51.4	17.200	64
					4	2	2	4	5	1	3	7	3	6	4	5	4	9	4	4	4		51.6	21.029	69
F_3 means							1			1		1	1												
Montcalm														2	17	30	16	3	1				54.1	0.908	69
Beecher					6	6	7	4	3	2		2											45.3	3.858	30
F_2		1	1	6	20	11	2	8	5	2	2	1	2	2	2	4	2	2	1				46.2	18.974	74
				5	10	11	4	6	9	2	4	5	3		3	6	3	1					47.3	16.725	72
F_3 means						1			1				1		1	1	1								
Montcalm														2	17	30	16	3	1				54.1	0.908	69
Tulare					5	10	3		1														44.1	0.942	19
F_2		1	1	1	1	2	1		1		1			1		2	1						46.9	28.243	13
F_3 means	1		1		1	1				1				2											

Table II (concluded)

Days to heading of F_1 and F_2 hybrids and parental varieties																									
	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	Mean	Variance	N
Frontier									4	22	24	9	3	2	1									57.9	1.447	65
Bonneville											8	22	20	20	7	2								60.0	1.538	79
F_1							6		3	1														54.9	1.433	10
							3	3	4	1														55.3	1.020	11
						2	2	1	3	4														55.4	2.445	12
F_1 (Reciprocal cross)							3	2	3	1	2	2												56.2	3.358	13
F_2		1					1	1	2	7	3	7	5	5	6	6	3	5	1		2	1	1	60.9	14.154	57
F_3 means										2		2	1													

EXPERIMENTAL RESULTS

1. Observations on the F_1 and F_2 generations

(a) Early x early cross

The F_1 and F_2 data on days to heading are shown in Table II as collected in the field in replicate five. These data serve to indicate a quantitative mode of inheritance. The separate distributions are small and the number in each varies tremendously. The data indicate very strongly the effect of environmental influences on days to heading. The variation within parent lines varies from 0.818 to 3.858. The means are relatively stable.

The F_1 distributions from the cross Atsel x Tulare have mean values later than either parent. The F_2 means are even later with a preponderance of early plants indicating partial dominance of earliness.

The variances of the F_1 distributions are not significantly different from the variances of the parent lines, indicating the presence of a non-heritable component only. The variance of the F_2 distributions far exceed that of the parents and F_1 indicating a variance component due to

a heritable source in addition to the non-heritable component. A tendency for transgressive segregation for lateness is evident in the F_2 in which case there must be more than one locus involved in the inheritance of earliness in this cross.

(b) Early x late crosses

In the Atsel x Bonneville cross the variances of the parental checks are not homogeneous by the F test ($p < 0.01$) which makes any testing of hybrid variances of doubtful value.

The difference in the mean days to heading between Atsel and Bonneville is approximately 17 days, which makes the cross very suitable for this type of study. The F_1 means fall directly at the mid-point between the two parents, an indication of quantitative inheritance. The means of the F_2 distributions are in close accord with that of the F_1 and hence intermediate between the two parents.

By using the variance of Atsel as an estimate of the non-heritable variation, the F_1 variances do not differ significantly. The F_2 variances as before differ very significantly, indicating a variance component due to segregation of genes.

The cross Atsel x Frontier is another cross with a wide differential in mean days to heading of the parental

varieties. F_2 data only are presented in this cross. The means tend to be intermediate between the parental varieties and the variances, as before, indicate the occurrence of genetic segregation. These parental varieties show the degree of variation that might be considered as the mean variation for pure lines. (see Tables III to IX)

Montcalm and Atsel differ in mean days to heading by approximately eleven days. The F_2 means show a tendency toward partial dominance for lateness. The F_2 variances in each case are very significantly greater than that of either parent.

In the cross Montcalm x Beecher, there is less spread between the parental means and a significant difference between the two parental variances. Transgressive segregation for earliness tends to be present, which was not the case in the previous cross.

Montcalm x Tulare shows a spread between parent means intermediate between those of Montcalm x Atsel and Montcalm x Beecher. The parental variances are small and essentially equal. The F_2 population clearly shows the effect of segregation in the heading of individual plants.

(c) Late x late cross

The F_1 of Frontier x Bonneville tends towards earlier plants than either of its parents. The reciprocal F_1 cross has a mean value between that of the parents and F_1.

Parental variances are small but essentially equal. The variances of the F_1 are not significantly different from those of the parent varieties but the variance of the reciprocal cross is significant at the 5% level. The F_2 generation shows transgressive segregation, which indicates a difference of at least two genes between the parental varieties.

The F_3 means tabulated after each F_2 generation are from F_3 distributions which are too small in number to give very much information.

The differences in the variances found among the parent lines can be attributed partly to the number of individuals in each row, partly to the increased area sampled in longer rows, partly to the presence of more biotypes in one variety than in another and partly to sampling error.

Table II, besides showing a trend towards quantitative inheritance, illustrates to a marked degree the part played by non-genetical factors in increasing and decreasing the variance in the rows.

In summary, the data presented in Table II indicate quantitative inheritance with more than one gene pair segregating in the F_2 and with varying degrees of dominance between the different alleles.

Table IIIa

	Days to heading of F_3 plants and parental varieties																	1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	D.T.H.	Mean	Variance	N
Atsel				6	13	2	6	4	3	1	1								49.2	3.590	36
			1	5	11	3		6											48.5	2.338	26
Tulare				5	9	1	13	7	5	6	2		1					42	50.1	4.303	47
			5	8	13	1	2	18	2	4								42	49.3	4.638	53
F_3	3	6	7	8	15	1	3	3	1									42	47.3	3.744	47
			14	8	9	2	13	9										42	48.3	3.564	55
		1	2	7	21	1	9	11	3	1								42	49.0	3.254	56
			7	3	26	2	15	7	14	6		2	1					43	49.9	4.961	93
				5	7	2	7	9	10	3	2							46	50.3	4.045	45
							4	31	33	44	8	3	1					46	52.3	1.274	124
			4	6	16	6	17	44	24	17	3	1	1	1	1			47	50.8	4.420	141
				4	10	3	3	27	26	10	3							47	51.0	3.082	86
				1	9	1	10	28	17	32	8	2	3		1			47	51.8	3.680	112
							2	11	37	30	6	2						47	52.4	0.904	88
			5	8	14		5	15	15	17	3	2	1					47	50.6	6.407	85
			4	14	21	4	5	18	19	8	1	2						48	49.9	5.357	96
			3	9	14	1	5	25	17	5								48	50.1	4.148	79
			4	8	15	1	9	21	30	12	1							48	50.5	4.373	101
	3	7	22	13	2	5	39	14	3	1					1			50	49.6	5.680	110

Table IIIb

	Days to heading of F_3 plants and parental varieties																	1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	D.T.H.	Mean	Variance	N
Atsel				2	1	9	9	2	1	1								44	49.6	1.750	25
				5	3	16	25	3	4			1						45	49.6	1.951	57
Tulare					3	6	17	6	8									44	50.3	1.372	40
					1	8	26	7	3	1								44	50.1	0.872	46
F_3		2	13		1		1											42	46.2	1.316	17
		1	2	4	2	1	12	3										44	48.9	3.160	25
			1	6	1	5	10	4										44	49.1	2.302	27
			3	3		8	15	6										44	49.3	2.173	35
							21	9	4	1								44	50.6	0.664	35
		3	8	6	2	10	6			1								45	47.9	3.530	36
		2	4	4	5	8	8	10	3	4								45	50.4	4.674	48
	9	9	3	1	14	6	1											45	47.6	3.776	43
					2	6	7	11	11	2								46	51.7	1.722	39
	5	2	9	2	16	13		1		1								46	48.5	3.547	49
		1	2	3	4	12	2	15	7	1								46	50.8	3.519	47
					5	1	9	14	11	7	2							47	52.1	2.385	49
					1	12	18	13	8	3								47	51.4	1.436	55
						1	9	28	10	3								47	52.1	0.690	51
				2	1	10	11	8	16	4	2	1	1					47	50.9	3.324	56
				4	2	2	8	3	7	9	8	1						47	51.4	5.135	44
				9		2	5	7	14	10	4	1						48	51.1	5.147	52
					1	6	8	7	14		5							48	51.1	2.478	41
						5	5	3	15	4	14		2	1				50	52.3	3.731	49
					1	3	13	7	6	3	1							50	50.8	1.805	34

Table IIIc

	Days to heading of F_3 plants and parental varieties																	1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	D.T.H.	Mean	Variance	N
Atsel				4	1		5	6	6	1	2	1						57	50.8	4.825	26
						4	10	5	3	1	2	1						44	50.9	2.666	26
Tulare								6	19	5	13	4			1	1			53.0	2.770	49
			1	3	1	2	10	15	4										50.2	2.257	36
F_3			3	2		1	5	8	3	1		1						52	50.1	5.244	24
						1	1	4	14	8	17	7	1	2				59	53.2	2.554	55
			2	2		3	4	19	12	1	1	1						52	50.8	3.134	45
			6	3	1	1	5	4	6	3	3	4	1					53	50.7	9.647	37
			2	8	1	1	6	17	7	4	1							50	50.3	4.412	47
									19	7	10	6						57	53.1	1.288	42
								7	12	4	9	2	2					57	52.8	2.104	36
						1	3	4	15	7	11	1	1	1				56	53.6	2.516	44
						2	1	9	6	1	13	2	4					56	53.8	3.758	38
	2	2			1	12	6	19	2	3	1							56	51.1	3.567	48
		4			1	4	3	8	2	1		1						54	50.9	5.297	24
		3			2	7	3	21	5	3	4			1				53	51.8	4.403	49
	2	2				1	6	7	4	4	2		1					56	51.8	6.904	29
							2	8	11	9	9		2	1				59	53.7	2.423	42
		3			2	3	4	2		2								51	50.3	4.763	16
					1	7	6	10	7	6	5	2	1					57	52.5	3.709	45
	4	4				5	10	14	4	2			1					55	50.8	5.858	44
						5	1	16	4	7	2	1	1	1				58	52.7	3.442	38
	3	4			4	7	12	14	3	4								51	50.7	4.403	51
		1				1	4	16	9	3	4		1					56	52.5	2.729	39

Table IVa

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel		4	4		7	16	13	7	2	2	1	1		1													44	51.4	5.478	58
			12	7	11	10	2	5																			48	50.0	2.563	47
Bonneville													3	14	9	6	2	23	16	3	2						49	61.9	4.695	78
															1		4	14	9	5	3		2	2			56	64.1	3.712	40
F_3				1	1	9	8	13	11	24	8	5	3	4				1	1								41	54.5	6.569	89
						2		2	7	19	20	10	12	7	3	2		2	5	1							44	57.0	8.165	92
							11	9	5	11	7	5	1	2		2											45	54.7	5.292	53
	1	5	7		2	14	12	13	9	3	5							2	2								45	52.4	13.105	75
	2				1	4	6	6	11	9	1	4	1	3													45	56.1	7.942	42
	1			5	7	8	9	9	4		2																46	53.6	3.791	45
	1		2	3	1	10	8	11	7	3	4		3														46	54.6	6.278	53
				1		6	6	4	10	4	5	1	4	1					4								47	56.7	10.314	46
						5	4	2	8	5	5	6	1	4		4		3									48	57.8	10.780	47
					1	2	5	3	28	4	3	3	3	3				5									48	57.1	8.082	60
1			2		7	11	6	24	25	13	4	5	4	2		1											48	55.5	6.020	105
						3	1	12	23	13	20	16	4	4		3	3	2									49	57.7	6.250	104
					1	3	5	18	26	13	14	9	2		1	1	2										50	56.7	4.605	95
									2	2	5	10	5	9	8	19	12	3	3	1	1	1		1			50	62.0	8.074	82
					1	2	11	31	9	2	2	3															54	55.2	1.804	61

Table IVb

	Days to heading of F_3 plants and parental varieties																										1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel			1	16		4	3		1	1																		45	49.0	3.078	26
				4	4	8	10	2	2	1																		45	50.4	2.245	31
Bonneville												1	1	2	9	2	4	12	2	2								53	60.6	3.829	35
													1	6	9	2	4	10	2		1	1						53	60.5	4.485	36
F_3								4	11	19	9	3	1			1												48	54.1	1.968	48
						3	5	15	4	11	6	1	2		1		1											48	53.3	4.875	49
						1	8	6	1	5	7	5	4	2	1	1		1										49	54.4	7.991	42
											6	4	4	2	13	3	2	7	2									49	58.8	6.040	43
		1	7		6	6	5	17	9	7		1																49	51.2	5.281	59
						4	6	2	3	10	15	8	2															50	53.9	3.953	50
						6	6	9	2	14	7	7			1													50	53.3	4.374	52
	1		3	7	3	6	4	3	2																			50	51.5	3.901	29
				1	5	4	11	6	9	8	1	5	1															51	54.3	4.772	51
								2	1	4	11	5	4	4			5	1										51	57.4	6.790	37
				2	1	9	6	4	7	8	5	3	2	1		4												51	55.2	9.425	52
		2		4	1	6	11	10	8	6		1																52	53.4	4.367	49
								1	12	4	3	8	6	5		7	6	1	1	1								53	58.8	10.089	55
					1	1	4	4	10	16	7	2	2	6		2												53	56.3	5.564	55
										4	4	9	3	6	2	14	8											54	60.1	5.480	50
										7	5	6	2	7	6	2	7	3	4		1							54	59.3	9.258	50
									4	6	6	2	7	6	3	1	1	2										54	57.5	6.149	38
										2	2	3	4	3	5		7	6	1		3							55	60.4	9.340	36
								1	9	8	9	4	7	2	1	1	4	2										55	56.9	7.431	48
											1	1	2	4	7	3	11	8	1	3		1						56	61.4	5.129	42

Table IVc

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel					4	10	5	3	1	2	1																	44	50.9	2.666	26
			2		3	6	4	3	1																			45	50.2	2.509	19
Bonneville																	4	14	7	19			2	2				65	63.3	2.687	48
														3	6	7	7	7	11	3	4							62	61.5	3.956	48
F_3		1	10		3	7	4	3	1		1		1															55	49.6	6.778	31
		1	4		4	10	6		2			1	1															57	50.2	5.862	29
							5	13	15		1	1																57	52.5	1.081	35
									15	15	11	1	2		1	1	2											59	54.6	4.031	48
					2	2	4	5	10	3	13	1			2	1		1										59	53.8	7.262	44
						3	7	3	7		4	2																59	52.5	3.458	26
					1	4	2	4	13	14	5		4	2			1											60	54.7	5.161	50
	1		1			2	4		5	7		3	1															61	53.8	6.804	24
						1	2	4	10	10	5	2																61	54.4	1.890	34
									1	4	23	9	8	4														61	55.8	2.145	50
			1	3	3		1	12	15	4	4	4	1	1	1	1												62	55.0	7.140	51
							1	3	9	2	9	14	1	2	3	1												64	57.1	4.300	45
							1	6	10	10	4	5	1	3	6	1												64	56.9	5.999	47
							1	5	6	1	7	8	3	3	5	9	1		1									64	58.4	8.980	50
								4	9	4	8	12	1	3	8	6	1	1										65	58.1	7.324	57
						2	2	8	3	6	4		4	1	2	8	2											65	57.4	12.052	42
				1	4	2	6	6	8	4	3																	65	54.0	3.545	34
												2		6	17	2	4	6										66	61.4	2.474	37
			1	1	3	1	7	8	5	5	11	7			2	4	1											66	56.7	8.709	56
						1	2	6	1	4	1				1	1	1	1										66	57.0	10.333	19

Table Va

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel		1	5	11	3		6																					43	48.5	2.338	26
			4	4		7	16	13	7	2	2	1	1		1													44	51.4	5.478	58
Frontier																	1	1	8	37	11	1	3	1				54	64.2	1.231	63
																			2	21	15		2	1				60	64.6	0.953	41
F_3			3	8	2		29	21	31	20	23	45	23	10	10	10	3	1										41	54.5	9.201	239
							1	2	4	10	18	28	10	2	11	4	3	2										43	56.3	5.014	95
						1	6	9	13	5	16	14	11	2	3	2	1		3	2								44	55.3	9.378	88
							5	5	19	9	15	25	28	8	18	5	6		9	2								45	56.6	2.569	154
									16	15	26	29	7	2	4	1		1										48	55.3	2.231	101
				3	1	4	26	23	13	20	9	8	5	6	3	2	2	1										48	58.5	7.964	126
	4	5	10	6	9	8	2	3						1														49	54.4	5.227	48
	3	4	5	6	18	31	19	5	9	4			4	3														50	56.4	7.066	111
			2		9	13	19	13	18	17	14	5	23	11	3	1	2		2	1	1							50	60.0	11.640	154
		4	10	9	17	8			2	2	1		1	1	1													51	55.3	8.186	56
		3				10	22	12	25	12	7	2	16	2	5													52	59.3	7.598	116
		1	5	9	35	12	12	8	3		2		2	2														52	56.1	5.319	91
	5			3	3	7	25	15	38	20	8	6	28	23	5	1												52	59.9	9.857	187
						5	13	14	20	7	2	3	12	5	4	2												56	59.9	7.507	87
					7	16	11	5	4	2	2	1	1															60	57.2	3.431	49

Table Vb

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel			2		9	15	2	2		1																		49	49.8	1.740	31
			1	16		4	3		1	1																		45	49.0	3.078	26
Frontier																					4	8	7	19	4	2		60	67.4	1.640	44
																			2	1	12	10	7	9	8	2		62	66.7	3.083	51
F_3							4	6	3	10	7	5	1	1															53.9	3.188	37
							1	3	4	20	4	1		1	1	2	2	2	1									50	55.3	9.418	42
									6	17	3	6	1	1	1													50	54.6	2.071	35
									3	3	5	7	4	4		3	4	1	1		2	1						51	57.7	12.103	38
										4	5	8	4	8	3	1	2	3	3									51	57.7	7.222	41
							2		11	10	11	4	1	1	1	1			1									52	54.7	4.844	43
			2					6	4	4	4	8	7	4		2	2											52	57.4	7.430	43
								1	2		3	6	1	4	3	5												54	59.0	5.667	25
		2	2	10	14	11	1	2	1																			54	54.1	2.019	43
			2		10	12	7	4	6	1	1		1															55	55.8	3.959	44
				2	5	8	11	3	8	1	2	1	2	1														55	56.7	5.757	44
						1	2	2	7	12	4	5	7	3	1	1	1											55	60.0	5.598	46
					1	8	3	2	14	4	3	2	6	6	2				1									56	59.1	9.680	52
					1		11	2	11	9	3	4	6	7	1	1		1										56	59.4	7.924	57
								4	7	8	3		4					1									56	59.3	4.755	27
					1	9	18	10	12		5	2	1															57	57.0	3.105	58
						1	3	7	12	5	3	3	6	4	1	2		1										59	59.8	9.695	49
					3	4	4	3	4	2	4	2	4															60	57.9	6.990	30
						4	9	8	15	13	6	2	5	2														62	58.4	4.075	64
									1	2	1	2	4	3	4	7	9	8	2	9		1						63	65.4	8.888	53

Table Vc

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Atsel			4	1		5	6	6	1	2	1																	57	50.8	4.825	26
					4	10	5	3	1	2	1																	44	50.9	2.666	26
Frontier																	2		9	14	3	3	2		1			68	64.1	2.553	34
																		1	3	17	14	3	4	1	2	1			65.0	2.733	46
F_3				2	1	3	2	13	3	9	9	1	1		1													58	53.0	5.000	45
							1	1		5	10	4	8	5	3			3	3	4	2							59	57.8	13.428	49
							3	14	8	12	3	4	4	1	1		2	2										60	54.3	7.691	54
					1		1		3	9	5	3	4	3			1	3	1									61	55.9	10.289	34
								1		3				3	2	1		2	1		1		2	1				62	60.0	24.375	17
							1	9	6	7	9	5	8	6	3		1	3	1									63	55.6	8.483	59
			2	8	8	8	10	11	4	2	1																	63	53.5	3.613	54
									3	11	23	9	5	3	3	1												64	58.5	2.429	58
			2	2	2	4	6	5	5	7	7	2	2		2	3	3											64	56.6	13.609	52
			2	2	2	2	4	12		4	1				1													64	54.5	6.189	30
							1	2	2	3	2	4	2	9	11	7	5	3	1									65	61.0	8.078	52
							1	7	5	3	2	3			1		2		1									65	57.6	10.507	25
									2	3	6	10	2	9	5	5	3			2								65	60.4	6.600	47
			5	6	5	10	1	1			1	1																65	52.4	4.455	30
											4	4	7	8	10	3	1		2		1							66	61.2	4.794	40
										1	1	5	12	1	2	1	2	4	2									66	59.2	6.447	31
											1	5	7	8	1	6	6	8	2	2								66	60.4	6.070	46
							1	2	2	4	11	11	6	4	12	3	1	2	2	2		1						67	60.3	9.531	64
				1			5	23	4	5	5	1	2	4	2	2	1											68	56.8	8.073	55
					2		3	2	2	4	6	7	2	3	1	5	3		2									68	59.1	12.702	42

Table VIa

	Days to heading of F_3 plants and parental varieties																																		1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	D.T.H.	Mean	Variance	N
Montcalm														4	7	19	5	6		1	1		1													51	59.4	3.131	45
															5	19	13	4	6	1		1													52	59.9	2.094	49
Atsel					8	3	4	6	4	3	1																									44	50.3	3.493	29
					4	6	8	7	5	2	3		1																							45	50.8	3.736	36
F_3	1	4	4	11	8	5	13	35	4	1		1																								38	49.5	4.625	87
				2	7	2	3	17	4	3	5	1	2																							41	51.1	5.173	46
			3	6	12	3	9	14	10	10	1	1																								42	50.2	4.916	69
			2	4	10	2	6	25	17	12	2	4	2																							42	51.1	4.876	86
				1		1	1	1	6	9	11	7	10	2	3																					43	55.0	4.795	52
					1	3	9	9	13	8	6	2	1																							43	52.8	2.982	52
				1			6	7	15	9	4	15	7	9	3	6	3			2																44	54.5	9.858	87
				3	12	1	14	24	10	3	4	2		8	1	4		1																		45	51.8	10.492	87
					1	1	5	3	3	3	3	10	3	7	5	2		2			1															45	54.9	11.667	49
	1	4	3	4	3	2	11	6	18	10		8	6	3	8	1				2																45	53.3	15.340	90
					1	3	9	12	15	11	11	9	8	4	6	2				1																46	54.4	7.562	92
										1	2	28	40	16	4	3				1																48	57.0	1.488	95
											4	13	20	17	17	8	4			7	2															53	58.4	4.697	92
																	1	4	4	16	21	6	20	9	9	19	10	8	7	2		1	6			60	68.1	13.250	143
																						2	1	13	13	28	12	5	4	3		2	3	1		64	70.4	5.689	87

Table VIb

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Montcalm													1	4	3	16	9	13	4	2								63	60.8	2.445	52
																10	4	17	16		1		2					64	62.1	2.418	50
Atsel				4	7	24	6	8																				44	50.1	1.250	49
				1	3	13	5	1		1																		45	50.3	1.326	24
F_3						1				6	12	24	4	2	2														55.7	1.940	51
			3	6		4				2	2	8	6	19	12	4		1										45	56.0	16.225	67
	1	3	4	4	4	16	11	4		2																		46	49.7	3.833	49
	3	2		7	2	10	7	2			2	3		4	1													46	51.0	14.474	43
			2	4	3	9	9	6		3	2	5		2	1													47	51.8	9.208	46
			1	2	2	5	7	8	4	6	3	3		6	1	2	1											47	53.4	11.713	51
	1	1		5		5	7		1	1	2		1		3	1	1											48	52.1	18.995	29
						7	9	8	3	5	2																	48	51.9	2.349	34
				3		1	6	3	2	1		1	2	2	2	2	1											49	53.9	16.666	26
					2	3	3	7	8	10	3	4		2														50	53.2	4.500	42
										4	6	9	6	14	2	7		3										54	57.4	4.407	51
							1	2	2	8	7	2		4	3	1	1		1									54	55.7	7.886	32
										6	9	18	3	5		2												54	56.0	2.095	43
						2	1	3	4	8	2	1	1	3	2			1	1									55	54.9	10.480	29
				1		3	1	3	2	5	1	2		3	2	1												55	54.2	10.840	24
															3	3	1	1	3									56	60.8	2.764	11
									3	4	7	11	2	9	2	3			4									56	56.9	7.064	45
											1	3	2	12	8	3	3	4	5	1								58	59.4	5.174	42
												5	3	9	7	10	4	7	3									58	59.4	4.124	48
											2	1		5	4	3	4	12	7	2	1		2	1				59	61.3	8.203	44

Table VIc

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	D.T.H.	Mean	Variance	N
Montcalm															4	4	9	19	5	4	2	2						67	62.0	2.748	49
												1	2	5	6	9	5	17	7	1								68	60.7	3.553	53
Atsel			4		4	12	6																					46	49.6	1.686	26
						17	10																					43	50.4	0.233	27
F_3			7		3	8			1																			52	48.9	2.877	19
					1	5	7	10	9	3	2	2		2		1	1			1								53	53.1	9.562	44
			2		3	4	4	4	1		1	1	1	1							1							54	52.0	16.044	23
			1			5	3	2	2		1	2	4	4														54	53.6	11.810	24
		3	5		1	4	6	6	3		1	3	4	7	3	2	1	2	5	3				1				55	55.0	29.966	59
			2			2	4	4	7					1														58	51.8	5.461	20
						4	2	2	5	5	5	1	1	2	1	1		2										58	55.5	10.923	31
				2	3	5	1	11	4				4	5	8	4	1											59	56.1	12.946	48
	1		3	3	9	5	9	8	1	2	4	2				1	1											59	54.2	8.264	49
								6	17	2	3	1																59	55.2	1.005	29
				2	7	7	6	5	1	1																		59	52.4	2.180	29
					5	4	7	6	7	1	1	3	2				1											59	54.3	6.836	37
				4	6	10	6	9	5		3	4		1														59	53.5	6.043	48
				1	1	2	5	12	9			1	2		1													60	54.4	4.735	34
				2	1	5	7	11	12	2	4	1	2	1		2	2											60	55.0	9.018	52
				1	5	8	4	11	2		1			1														60	53.2	4.216	33
					4	6	1	7	13	6	4	1	2	2	1	2						2						61	55.7	12.772	51
				2	1	6	3	10	7	2	2	4	1	1	1													61	54.6	6.651	40
	1				6	3	3	9	2	2	4	1	3	1	1		1					1						62	55.1	14.159	38
					4	3	2	4	7	1	2	1	2			6	2	1	2	2	5	1	2	1	1			63	59.6	38.250	49

Table VIIa

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	D.T.H.	Mean	Variance	N
Montcalm															15	33	21	12	3	8	3	1	1		1			54	60.1	3.721	98
														5	12	14	12	3		1								55	59.0	1.565	47
Beecher			1	5	9	3	13	14	3																			40	49.6	2.504	48
				13	20	7	5	5	2																				48.5	2.019	52
F_3	1	1	12	6	8		15	2																				38	48.0	3.568	45
				2	4	3	9	9	3	1	1	3	7			1	1											39	51.8	10.277	44
				5	5		14	9	5	1	1	8	5	2														39	51.5	8.623	55
			2	3	4	1	4	12	8	5	2	5	2	1	2													40	51.7	8.587	51
		1	5	5	5	11	7	2	2	1	1	3	1	2	1													40	50.9	10.619	47
	3	7	15	6	3	2	5	1	3	3	2	4																42	49.2	11.243	54
		1	6	6	2	6	12	3	2		2	2		1	1													43	50.6	9.033	44
			1	3		12	12	1	3	1	4	3	4															44	51.9	7.527	44
			2	6	1	6	33	23	6	9		2	5	7	7	4	2	2	1									44	53.3	13.554	116
				2		6	10	4	9	1	3	2			3	2			2	1								45	53.5	15.755	45
			5	4	1	8	15	5	1	3	1	7	2															50	51.5	8.137	52
								1	9	6	7	21	16	13	4	9	7		6	2								52	57.3	7.979	101
								1	9	17	31	29	3	3														53	55.1	1.409	93
									1	7	11	9	27	13	8	17	8		3									53	57.7	4.984	104
								4	2	5	12	13	9	7														55	55.6	2.795	52

Table VIIb

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	D.T.H.	Mean	Variance	N
Montcalm														4	14	9	5	8	5	3								60	59.5	3.105	48
													1	1	8	10	20	2	5	2	1							62	59.8	2.461	50
Beecher					3		6	16	4		1																	46	50.7	1.513	30
					1	3	21	1																				46	49.8	0.295	26
F_3									3	1	8	10	10	2	12														55.7	3.202	46
	4	8	12	3	11	3	4																					43	46.8	3.098	45
		3	3	2	8	9	14	7	1																			44	49.0	3.085	47
		4	3	2	11	3	7	3		1	3		1	1	6													44	50.4	16.734	45
	2	3	8	6	11	3	2																					44	47.1	2.316	35
			1	3	11	6	16	4	3	3	2	1	6		2	1												45	50.9	9.865	59
			2	5	4	12	6	7	2	1			3	2	7	1												46	52.1	12.252	52
			1	6	2	21	18	6	2																			46	50.3	1.610	56
1	7	1	9	9	14	2	2		1	3	1			2														46	49.7	8.845	52
				2	10	8	11	2	2		2	2	7	1	2	1	1											46	53.5	13.213	51
	1	2	3	6	16	4	5	3	1	1	3			5		1												47	51.5	11.054	51
		1	6	5	8	8	4	2	2	1	1				1			1										48	51.1	9.074	40
	2	1	2	3	8	5	8		1	2	4			3	1	1												48	52.0	12.498	41
					9	7	7				3	10	13	6	1	1	1											48	55.2	13.408	58
						1	4	14	27	7	1	1																51	53.8	1.036	55
										2	9	13	18	4	1		1											52	57.4	1.613	48
					2	2	11	3	5	5																		52	52.8	2.249	28
						2	1	2	12	14	8			2	1		1											52	54.9	3.305	43
									4	4	3	3	13	8	7	1	6	1										56	58.3	5.617	50
											3	3	22	7	6	6	5		1									57	59.0	3.306	53

Table VIIc

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	D.T.H.	Mean	Variance	N
Montcalm															2	6	3	7	14	15	3	1	1		1				60.9	3.703	53
															1	3	11	4	9	5	5	1	2		1			71	60.8	4.567	42
Beecher									9	5	4																	55	51.7	0.683	18
							4	7	16	6	3	1																53	51.0	1.389	37
F_3				3	3	1	5	11	8		1																	52	49.5	2.967	32
			1	1	4	1	6	5	10	2			2	2	1	1	1											52	50.8	10.973	37
	1	2		2	5	1	7	6	1	1			2			2												52	49.3	12.961	30
						1	2		11	8	2	1			1	1	2		1									52	52.6	9.702	30
				1	5		1		14	2				3	5	2	1	1										52	52.5	15.726	35
			2		7	1	5		6	4	1	1	3	3	2	1		1										53	51.3	15.326	37
				3	1		2	3																				53	48.1	3.361	9
					6		2	6	7	2	1	2		5	4			1	1									53	52.1	13.898	37
					3		2	4	9	3		2	2		1	1				1								54	51.8	11.231	28
					1	4	3		10	4																		54	50.2	2.537	22
				1	4		3	6	9	1	3	1	1	2	2	1												54	51.3	9.487	34
								2	6	6	1	2						2	2									54	53.2	10.962	21
	1	2	1	3			4	5	4	1		1	2	1	2			2	1			1						56	51.5	23.256	31
				1			2	1	11	2	1	1	1	2	2	1	2	1										56	53.0	12.000	28
										2	1	25	12	4	2	1		1										57	54.6	1.851	48
								4	6	3	3	10	11	5	4	4	2											58	54.3	6.060	52
									2	10	8	18	8		1													58	53.5	1.560	47
									1	3	7	8	9	8	12	7	1	1	2									59	55.7	4.918	59
												1	6	5	10	10	7	2	3	3	3							62	58.1	5.398	50
									1						1	11	8	10	2	3	4	1						64	59.6	5.003	41

Table VIIIa

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	D.T.H.	Mean	Variance	N
Montcalm																4	9	25	7	3	2							52	59.0	1.264	50
																4	8	22	5	3		1						54	59.0	1.357	43
Tulare				1	19	30	21	7	5	7																		40	47.6	2.167	90
				1	7	9	9	2	5	10																		43	48.4	3.620	43
F_3		2	8	10	10	6	1			4		7			1													36	47.1	11.485	49
						3	19	3	7	37	3	8	1															39	50.3	2.970	81
							17	8	19	38	4	3	1	1	1													39	50.3	2.511	92
				1	9	31	36	5	7	21	6	1	4	13	9	4	1											40	50.0	11.047	148
				1	3	2	16	4	6	30	3	3	1		5	2	2	9	1	1								42	51.7	15.232	89
	1	2	3	5	7	10	6	1		7	3	1																42	47.4	7.488	46
				1	4	6	8	2	6	10	4			1	3		2	2										43	50.4	12.904	49
			2	2	2	1	5		2	15	1	5	1			1		1	1	1		2						45	50.1	21.398	42
		1	2	2	7	11	6	4	12	13	2	1	1	1	1													45	48.9	6.956	64
		1	5	1	2	2	4	2	3	8	3	4	1	1	1		1	3	1									45	50.5	20.302	43
		1	1	3	6	2		3	4	10	13	9	4	5			2		2	6		2	2					46	52.7	25.203	75
						1	3	1	1	9	16	5	5	7	19	18	21	19	2	3	1							51	55.7	10.109	131
		1	2	7	2	6	4		6	6				1	2	1	1	1	1			2						52	49.9	26.962	43
										1	3	12	12	26	50	44	19	20	8	3	1							52	56.5	3.795	199
					3	6		10	2	13	15	7	3	15	31	24	20	25	13	12	3	3	5					54	56.0	16.340	210

Table VIIIb

	Days to heading of F_3 plants and parental varieties																										1950	1951		
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	D.T.H.	Mean	Variance	N
Montcalm																	2	15	8	3	7	8	1					58	60.6	2.945	44
																1	6	7	5	5	2	2						59	59.8	2.565	28
Tulare						1	4	12	17	6	2																	43	49.7	1.146	42
							4	1	11	21	8		2															43	50.8	1.584	47
F_3			3		1	1	2	12	3	7		1		1	2	4	1	2											51.0	16.615	40
	4	9	20	6	2	1																						39	43.9	1.161	42
		7	9	4	3	2			1																			40	44.6	2.734	26
		6	5	2	5	4		1																				41	45.0	3.000	23
		3	4	4	3	2		18	4	5	2																	45	48.0	6.816	45
								7	9	17	7	3	1															46	50.8	1.486	44
		6	4	4	2	3	12	2	1	1																		46	47.3	5.291	35
		1	3	2	1	1	1	6	7	7	8		2	2	3					1	3	2	1					46	52.7	24.714	51
				1		4	15	12	13																			46	49.7	1.265	45
						1	8	9	17	3	1	4	1	2	1	1	3	1			1	1						46	52.4	13.747	54
						1	14	8	25	1	2																	46	50.3	1.187	51
			1	5	1		4		18	8	2	3	1	2			2	2										47	51.5	12.046	49
							4	5	21	6	9	3	1	2	5	1	1	2	2		1							48	53.0	11.143	63
	1	1	2	2	3	4	8	7	10		1		4	2	3													48	50.2	11.786	48
													10	19	10	2	1	1										51	56.3	1.195	43
							1	2	2	3		1	3	5	3	1	11	4	1									53	56.4	11.568	37
							2		4	5	3	3	1	2	1	1	8	5	2	2	4							54	56.6	18.477	43
															3	2	19	10	1	3	6							55	59.8	2.788	44
										1	6	2	4			1	5	11	8	3	7	3						57	59.2	12.708	51
									1	3	7	7	4		2	2	8	4	4	2	5	4		2	1			57	58.1	19.107	56

Table VIIIc

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	D.T.H.	Mean	Variance	N
Montcalm																1	2	12	11	5	11	1						65	60.3	2.005	43
																8	11	7	4	7	6	3	2		1				59.8	5.136	49
Tulare						5		5	8	2	3																	50	49.5	2.625	23
								2	1	11	4	3			1													52	51.5	2.164	22
F_3		1		2	1	1		2	1	3	5	3	1	1			1	1			2								51.8	23.557	25
	2	5	4						2	6	10	2	1															47	48.8	17.725	32
	4	7	3	2	2		1																					48	43.7	2.649	19
					1	13	1	7	15	5	5																	50	49.2	3.041	47
	1	5	1	2	2	8	2	2	4	2	2	1																51	47.3	8.938	32
				1		4		3	13	5	8	3	3	3														51	50.9	5.218	43
								1	4	3	5	1	1	3	1		2											52	52.7	6.434	21
								1	6	11	7	2	3	4		3	1	2	1	1	2							53	53.5	12.767	44
			2	2	3			4	3	6		1	1	1		1	2											53	50.4	13.686	26
	3		3	3	2			3	4		6	1	2															54	48.7	12.046	27
		1	6	1	2				13	5	3	1		1														54	49.2	7.778	33
								1	5	3	1	1		4	1	2	1	1	1	1	2		1					55	54.9	20.660	25
			1		2			1	4	1	2		1		1		3											56	51.7	16.763	16
									3	7	7	1	5	2			2	2	2		2	2						56	54.5	16.963	35
					1				1	1	3	1	5	3			3	3	1	2	4	3						57	56.8	20.561	31
								2	5	1	4		1	2			1	2	1		1							58	53.5	16.682	20
		2	6		2				1		3	7	11	6	1		2											59	51.8	16.695	41
										2	6	2	1		1	5	7	7	6	1	2	3						63	57.8	16.271	45
						1				1	2	1	2	4	2	10	10	7		1	2	1						64	57.0	8.789	44
						2				4	3	7	3	2	3	6	6	3	2	1	3	1	1					65	55.9	15.679	47

Table IXa

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	D.T.H.	Mean	Variance	N
Frontier								1		2	26	4	8	2	2													55	64.6	1.780	45
									1		24	22	4	8	3	2												57	65.2	2.007	64
Bonneville				2	3	6	11	10	1	11	1	1		1														50	60.9	4.340	47
						1	6	4	2	10	16	3			1													52	62.9	3.343	43
F_3		1	5	6	5	5	5	7	3	2	8	1																49	60.0	7.956	48
			2	3		4	2	3	1	2	5		3	5	1	1	1					3	7	4	2			50	67.5	58.880	49
			3	3	1	4	7	6	3	4	6	3	3	3					1				3		3	1		54	64.0	41.528	54
				2	1	4	1	2	3	7	6	6	6	2	1	4	1	3					1		2			54	65.1	23.428	52
			9	5	1	2	3	1	3	13	9	1																55	60.7	10.265	47
									1	5	26	14	11	1	4													56	64.8	1.686	62
	2	5	5	3	5	7	1	5	7	9	3				1													56	60.7	10.306	53
	3	6	6	3	6	1	2	4	8	6	2		1			1					2			1	1			57	61.5	28.831	53
									1	9	13	8	12	3	5	3	1											57	66.3	3.618	55
								1		7	2	5	4	4	7	3	3	7	5	1	2			2		1		58	68.4	16.081	54
		1		3	1	4			2	5	17	7	2	1		2	3				2		2	2	1			60	65.3	25.721	55
	1	4	6	2	7	5	6	4	3	9	2	1	2			1							2	1				61	61.8	20.464	56
								1	1	2	10	5	4	8	10	3	3	1		1				6	3			62	68.1	21.020	58
										2	10	8	11	10	5	3		1										63	66.0	3.020	50
						2		1	2	7	16	5	2	6	3	2		1										64	64.7	5.787	47

Table IXb

	Days to heading of F_3 plants and parental varieties																									1950	1951		
	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	D.T.H.	Mean	Variance	N
Frontier									4	24	8	8	3	1	3	1												61	64.0	2.783	52
											1	2	7	14	12	11	2			2								62	67.7	2.834	51
Bonneville -						4	11	3	17	10	1	1		1															61.6	2.659	48
									1	19	18	13	4	3	3	1													64.4	2.313	62
F_3									4	13	11	9	4	4		1													64.3	2.474	46
						5	1	2	3	8			5	7	2	4	2	2		1		1	1	1	1				66.1	23.973	46
		1	3	3	4	6		1	12	13	1		1			1													60.9	8.462	46
	1	5	18	4	11	4	1	1	1	3																		50	57.4	4.696	49
		6	9	4	5	4	2		5	1	1	1	2	6														51	59.7	17.432	46
		1	6	6	1	4	3		5																			52	58.3	5.275	26
	2	3	4	4	6	4	4		1	1	3	4		1	2													53	59.7	16.050	39
		10	9	7	3	1	2		4	1	3	1	1	1														53	58.3	12.597	43
		1	3	6	5	3	6	3	7	5		3	2															54	60.3	8.610	44
	3	2	5	2	5	2	3	5	12	8				2														54	60.0	10.437	49
		2		3		3	3	3	8	16	13	5	5	3	1													54	62.8	7.484	65
		3	4	4	7	5	4	5	17	5	2																	56	60.0	6.509	56
		2	6	2	9	3		3	15	7	7	4																56	60.7	8.983	58
		1	1	2	2	1	1		2	5	4	3	10	3	4	2	5		1									56	64.7	16.760	47
					2		2	3	8	7	5	1	4	4			1			1			2	3	1			57	65.4	28.987	44
									1	12	13	7	8	8		2												59	64.8	2.815	51
										3	14	9	9	10	1	2			1				1					60	65.8	5.247	50
										2	1		1	5	2	2	3	5	1	3			6	7	1			61	71.6	19.973	39
									2	20	18	7	2	4	1		1	1										62	64.3	3.190	56
								1	5	3	3	2	4	7	6	4	3	5	2			1	1		1	1		63	67.7	16.975	49

Table X

Correlation (r) between days to heading in 1950 and mean days to heading in 1951 for each replicate (R) and each cross.

Cross	R	N[1]	r	P
Atsel x	1	15	0.566	0.03
	2	20	0.725	< 0.001
Tulare	3	20	0.837	< 0.001
	Total	55	0.720	< 0.001
Atsel x	1	15	0.408	0.13
	2	20	0.747	< 0.001
Bonneville	3	20	0.864	< 0.001
	Total	55	0.163	0.20
Atsel x	1	15	0.493	0.07
	2	19	0.665	0.002
Frontier	3	20	0.491	0.03
	Total	54	0.309	0.03
Montcalm x	1	15	0.974	< 0.001
	2	19	0.835	< 0.001
Atsel	3	20	0.676	< 0.001
	Total	54	0.540	< 0.001
Montcalm x	1	15	0.821	< 0.001
	2	19	0.897	< 0.001
Beecher	3	20	0.888	< 0.001
	Total	54	0.608	< 0.001
Montcalm x	1	15	0.746	0.002
	2	19	0.956	< 0.001
Tulare	3	19	0.798	< 0.001
	Total	53	0.689	< 0.001
Frontier x	1	15	0.289	0.23
	2	17	0.856	< 0.001
Bonneville	3	19	0.759	< 0.001
	Total	51	0.387	0.007

[1] Number of pairs of observations.

Table XI

Comparisons between the means of representative F_3 materials sown 3 weeks apart.

Cross	Replicate[1]	Mean of F_3	Difference[2]	N[3]
Atsel x	1	50.3	5	15
	2	50.2	5	20
Tulare	3	51.9	7	20
	5	45.0		12
Atsel x	1	56.1	4	15
	2	56.1	4	20
Bonneville	3	55.2	3	20
	5	52.2		2
Atsel x	1	57.0	6	15
	2	57.7	6	20
Frontier	3	57.4	6	20
	5	51.3		10
Montcalm x	1	55.5	7	15
	2	55.2	7	20
Atsel	3	54.2	6	20
	5	48.5		4
Montcalm x	1	52.6	2	15
	2	52.6	2	20
Beecher	3	52.7	2	20
	5	50.3		6
Montcalm x	1	51.2	6	15
	2	51.8	6	20
Tulare	3	52.0	7	20
	5	45.5		7
Frontier x	1	64.3	6	15
	2	62.6	4	20
Bonneville	3	63.5	5	20
	5	58.5		5

1. Replicate 5 seeded 3 weeks later than replicates 1,2 and 3.

2. Difference in whole days between replicate 5 and replicates 1, 2 and 3 respectively.

3. Number of F_3 means that determine mean of F_3.

Table XII

Differences in mean days to heading of parental varieties sown 3 weeks apart

Variety	Replicate	Mean	Difference[1]	N[2]
O.A.C. 21	1, 2 and 3	60.1	6	32
	5	54.4		7
Atsel	1, 2 and 3	50.2	7	30
	5	43.4		4
Beecher	1, 2 and 3	50.3	5	11
	5	45.2		2
Tulare	1, 2 and 3	49.8	6	15
	5	44.2		4
Montcalm	1, 2 and 3	60.3	6	27
	5	54.5		3
Frontier	1, 2 and 3	65.0	7	18
	5	58.2		3
Bonneville	1, 2 and 3	62.3	3	26
	5	59.1		3

1. Difference in whole days between date 1 (replicates 1, 2 and 3) and date 2 (replicate 5).

2. Number of rows represented in each mean.

2. Observations on the F_3 generation

(a) Correlation between 1950 and 1951 data

The F_3 distributions, as they appeared in the field are shown in Tables III to IX with the corresponding parental lines grouped at the top for convenience. Table a is of the first replicate, table b is of the second replicate and table c is of the third replicate in each case. Days to heading of each plant in 1950 (D.T.H.), the mean of each distribution grown from each plant in 1951, the variance of each distribution and the number of plants in each (N) are tabulated in columns at the right of each table.

The replicates each consist of plants whose progenitors were grown in distinct photoperiods in 1950. Therefore an overall correlation within a particular cross between days to heading of F_2 plants and mean days to heading of F_3 plants will not give a true picture of the relationship between the two without an adjustment between the three replicates. The separate correlation data are summarized in Table X.

It will be noted that the second replicate in each case gave consistently high correlation values between days to heading in 1950 and mean days to heading in 1951. This may be due to a greater similarity between the two respective

photoperiods or environmental conditions in general, i.e., replicate 2 in 1950 perhaps corresponded more closely to the photoperiod in 1951.

Replicate 3 also gave highly significant correlation values with the exception of the cross, Atsel x Frontier, which was significant at the 5% level.

In the case of replicate 1, the crosses involving Frontier and Bonneville showed no significant association between 1950 days to heading and 1951 mean days to heading. The environment may have had an effect which did not permit detection of the association.

These two varieties were perhaps most sensitive to photoperiodic conditions. Atsel and Tulare tend to be similarly affected but to a lesser degree. Of the two, Tulare appears to be the ~~most~~ more sensitive.

The correlation coefficients calculated from the combined data of the three replicates are not very informative since each replicate is from a different population.

Further evidence of the effect of the environment on mean days to heading is given in Tables XI and XII. Due to the varying number of F_3 lines grown in replicate 5, the data serve only to indicate an interaction between varieties in the cross and environment, presumably, light and temperature.

The data in Tables XI and XII are in agreement. Bonneville and Beecher seem to be the least affected by environment and crosses involving these two varieties seem to bear this out.

Table XIII

The number of segregating and non-segregating F_3 lines as determined by the F test.

Cross	Replicate	No. of Seg. lines	No. of Non-seg. lines	Hypothesized Ratio	Chi-square	P
Atsel x	1	10	5			
	2	5	15			
Tulare	3	10	10			
	Total	25	30	1:1	0.455	0.50
Atsel x	1	11	4			
	2	15	5			
Bonneville	3	14	6			
	Total	40	15	3:1	0.152	0.70
Atsel x	1	12	3			
	2	14	6			
Frontier	3	17	3			
	Total	43	12	3:1	0.297	0.60
Montcalm x	1	13	2			
	2	15	5			
Atsel	3	17	3			
	Total	45	10	3:1	1.364	0.25
Montcalm x	1	12	3			
	2	10	10			
Beecher	3	15	5			
	Total	37	18	3:1	1.752	0.15
Montcalm x	1	13	2			
	2	12	8			
Tulare	3	18	2			
	Total	43	12	3:1	0.297	0.60
Frontier x	1	12	3			
	2	17	3			
Bonneville	3	14	6			
	Total	43	12	3:1	0.297	0.60

Table XIVa

Frequency distribution of F_3 means (days to heading)

Atsel x Tulare

D.T.H.	f	Class	X_c	f	f^1	f Atsel	f Tulare
46	1						
47	1						
48	4						
49	4	49.5	48	10	8	2	1
50	9					2	4
51	18					2	
52	9	49.5 52.5	51	36	14		1
53	6						
54	3						
		> 52.5	54	9	8		
	55			55	30	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 50.9

Chi-square for goodness of fit to 1:1 ratio = 5.291

p = 0.075

Figure 1

Mean days to heading of F_3 lines from the cross Atsel x Tulare. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 3 phenotypic classes according to a 1:2:1 ratio (single-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

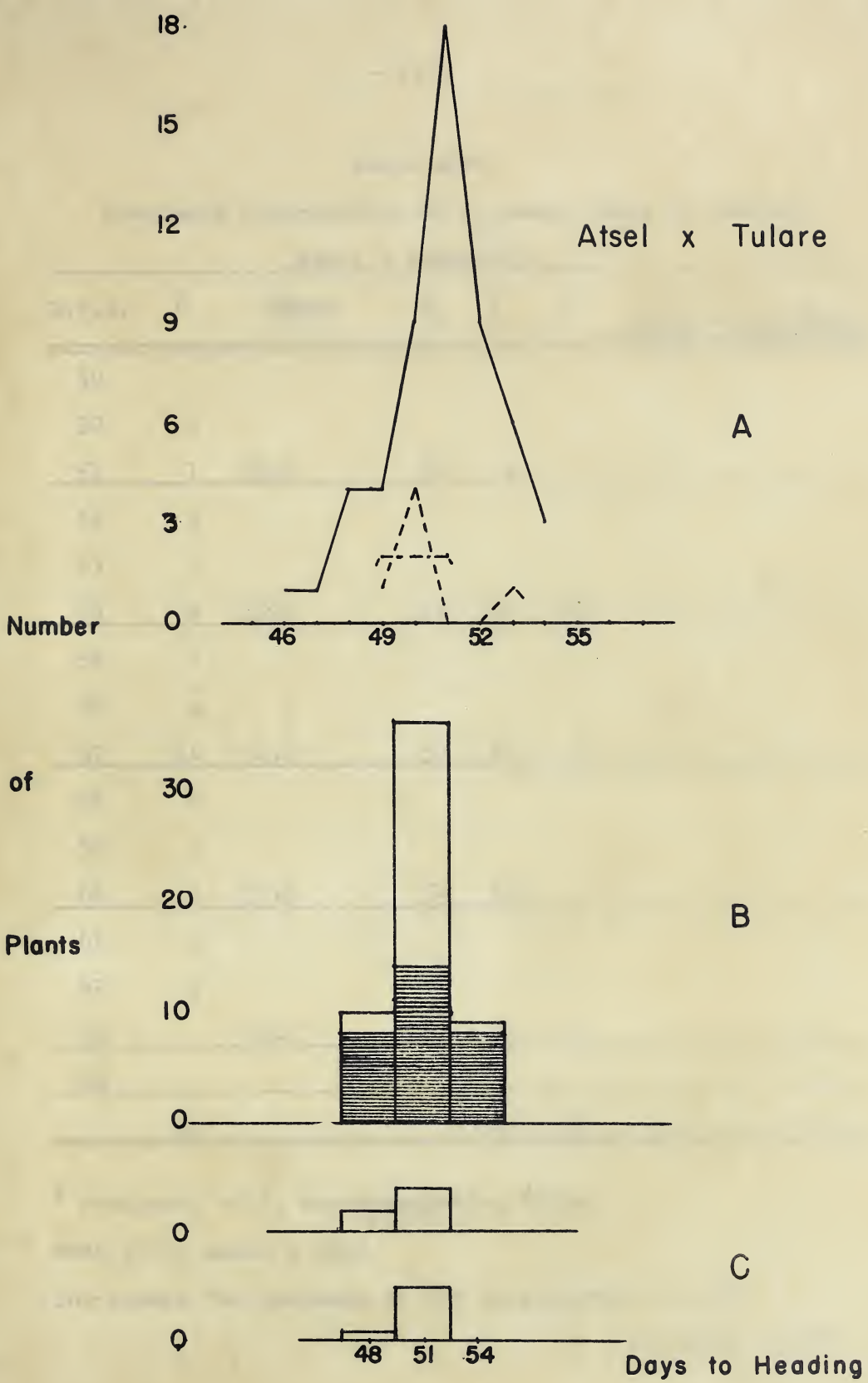
18
15
12
9
6
3
0
Number
46
49
52
55
Atsel x Tulare
A
of
30
20
Plants
10
0
B
0
C
0
48
51
54
Days to Heading

Fig. 1

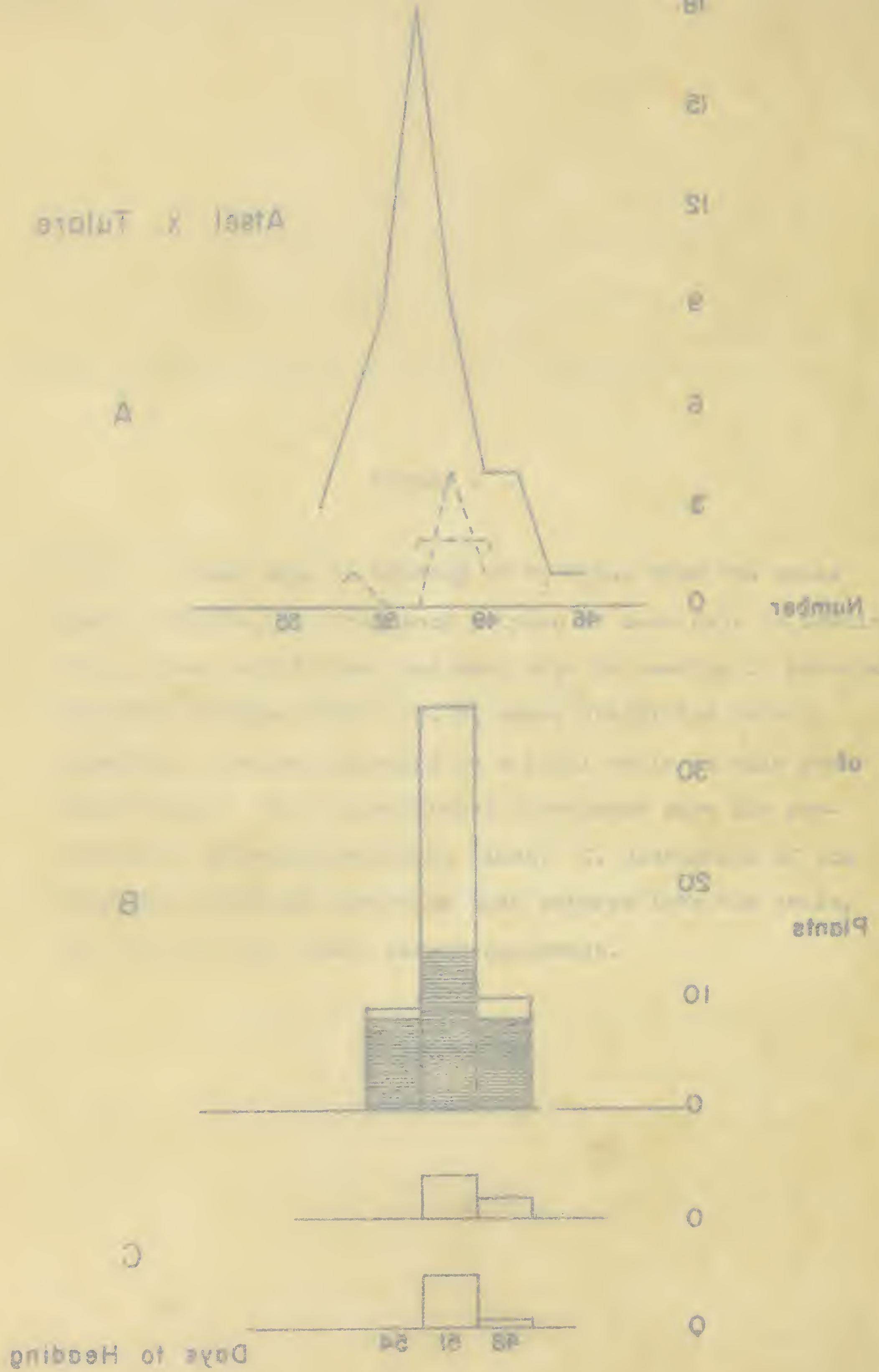

Fig. 1

Table XIVb

Frequency distribution of F_3 means (days to heading)

Atsel x Bonneville

D.T.H.	f	Class	X_c	f	f^1	f Atsel	f Bonneville
49						1	
50	2					3	
51	1	48.5	50	3		2	
52	2						
53	5						
54	9	51.5	53	16	10		
55	8						
56	4						
57	11	54.5	56	23	4		
58	5						
59	3						
60	2	57.5	59	10			
61	2						2
62	1						2
63		60.5	62	3	1		1
64							1
	55			55	15	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 55.8

Chi-square for goodness of fit to 3:1 ratio = 1.776

p = 0.70 - 0.80

Figure 2

Mean days to heading of F_3 lines from the cross Atsel x Bonneville. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross with that of the female parent uppermost.

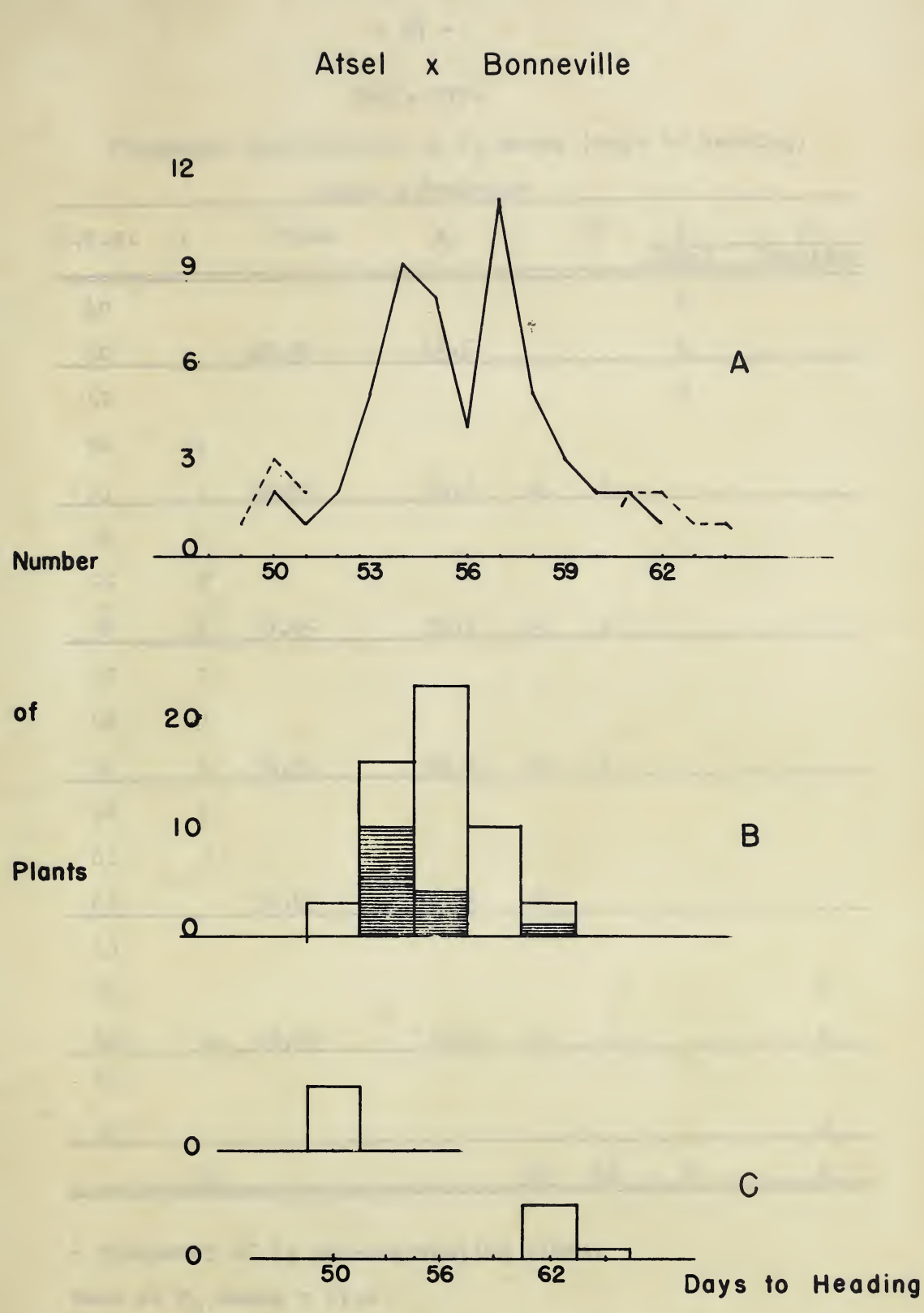
Atsel x Bonneville
12
9
6
3
0
A
Number
50
53
56
59
62
of
20
10
0
B
Plants
0
0
C
50
56
62
Days to Heading

Fig. 2

Atsel x Bonneville

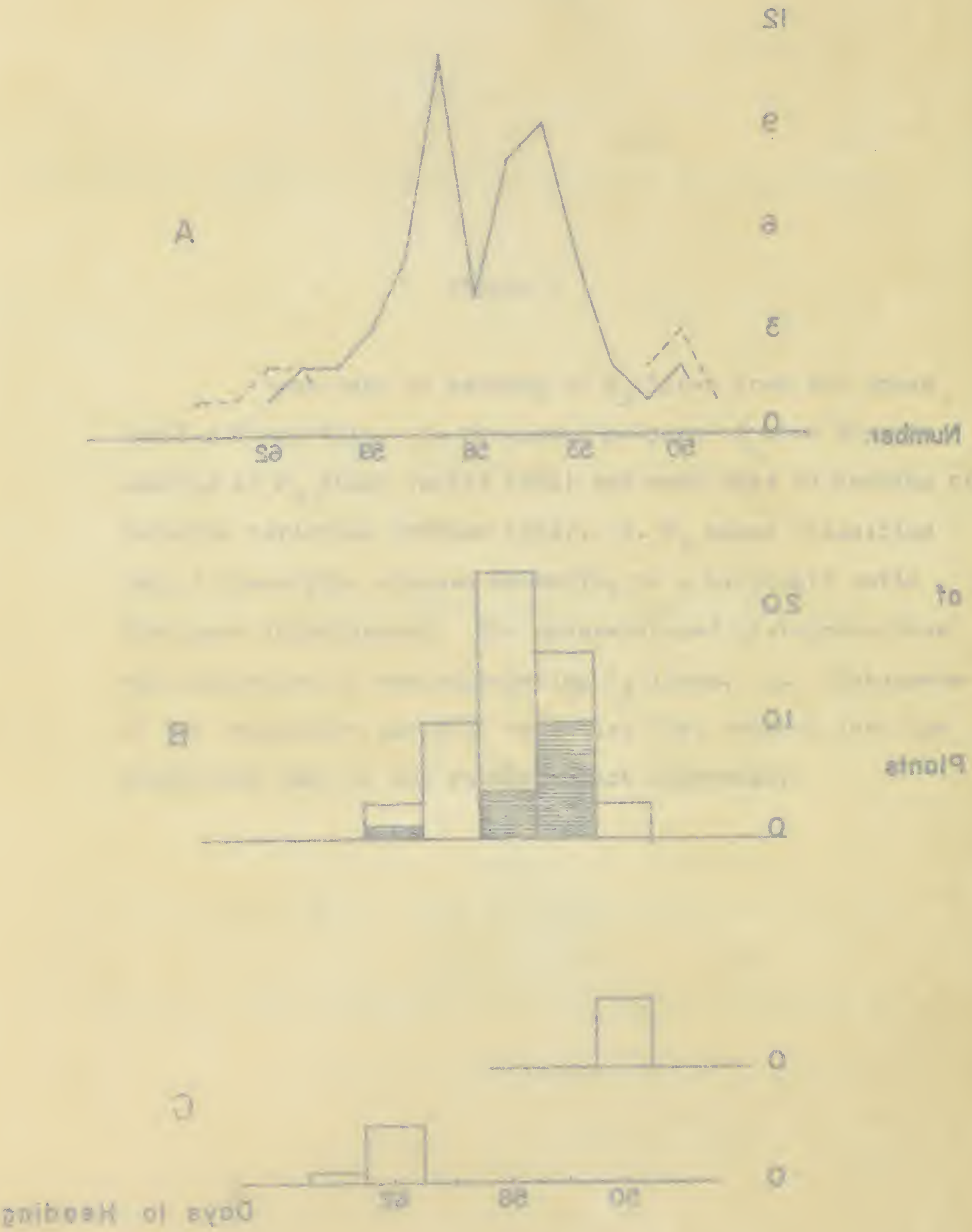

Fig. 2

Table XIVc

Frequency distribution of F_3 means (days to heading)

Atsel x Frontier

D.T.H.	f	Class	X_c	f	f^1	f Atsel	f Frontier
49						2	
50		47.95	49.5			1	
51						3	
52	1						
53	1	50.95	52.5	4	3		
54	5						
55	8						
56	6	53.95	55.5	19	5		
57	7						
58	7						
59	8	56.95	58.5	23	4		
60	9						
61	2						
62		59.95	61.5	8			
63							
64							2
65	1	62.95	64.5	1			2
66							
67							2
	55			55	12	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 57.4

Chi-square for goodness of fit to 3:1 ratio = 6.503

Figure 3

Mean days to heading of F_3 lines from the cross Atsel x Frontier. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

Atsel x Frontier

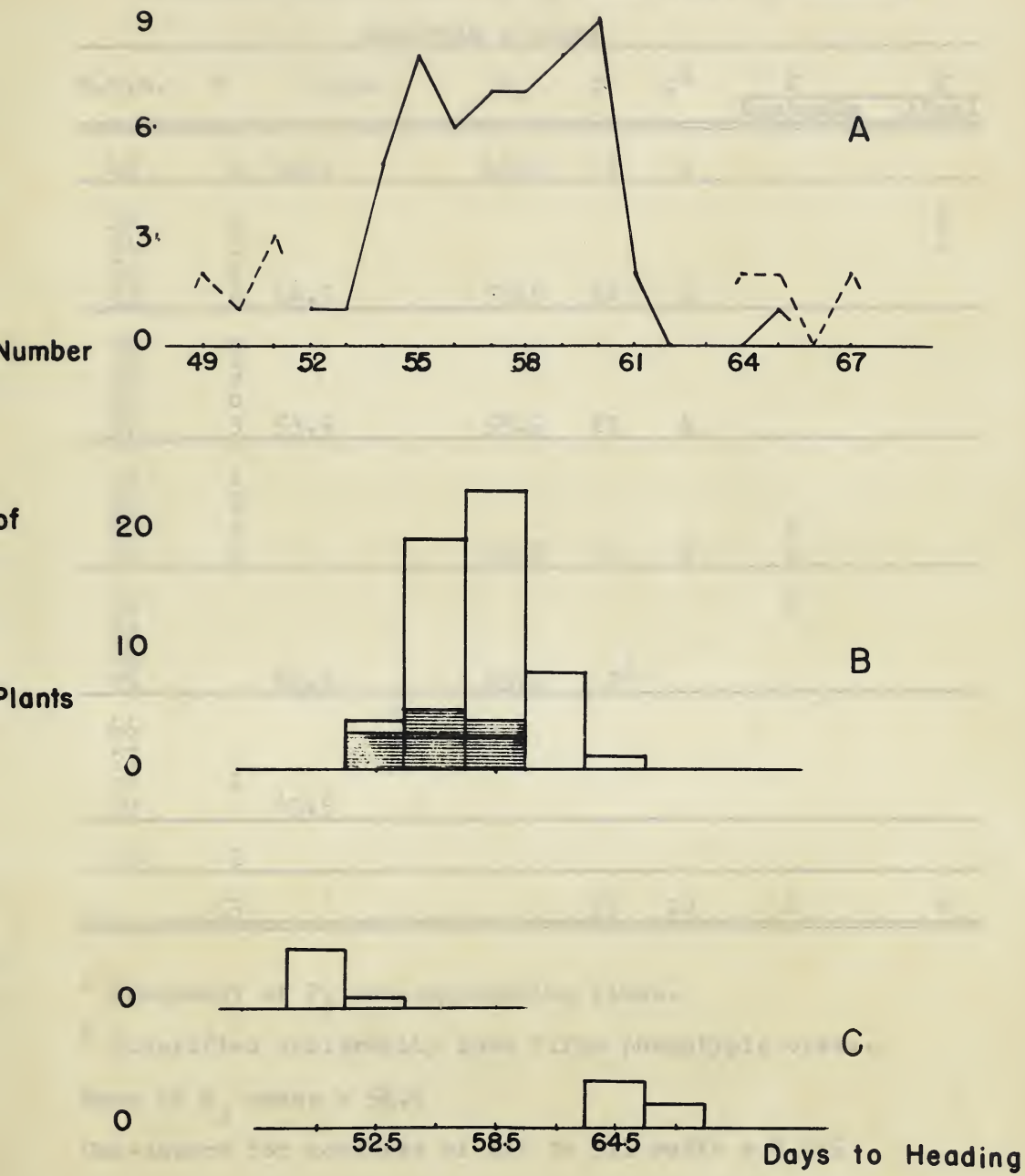

Fig. 3

Atsel x Frontier

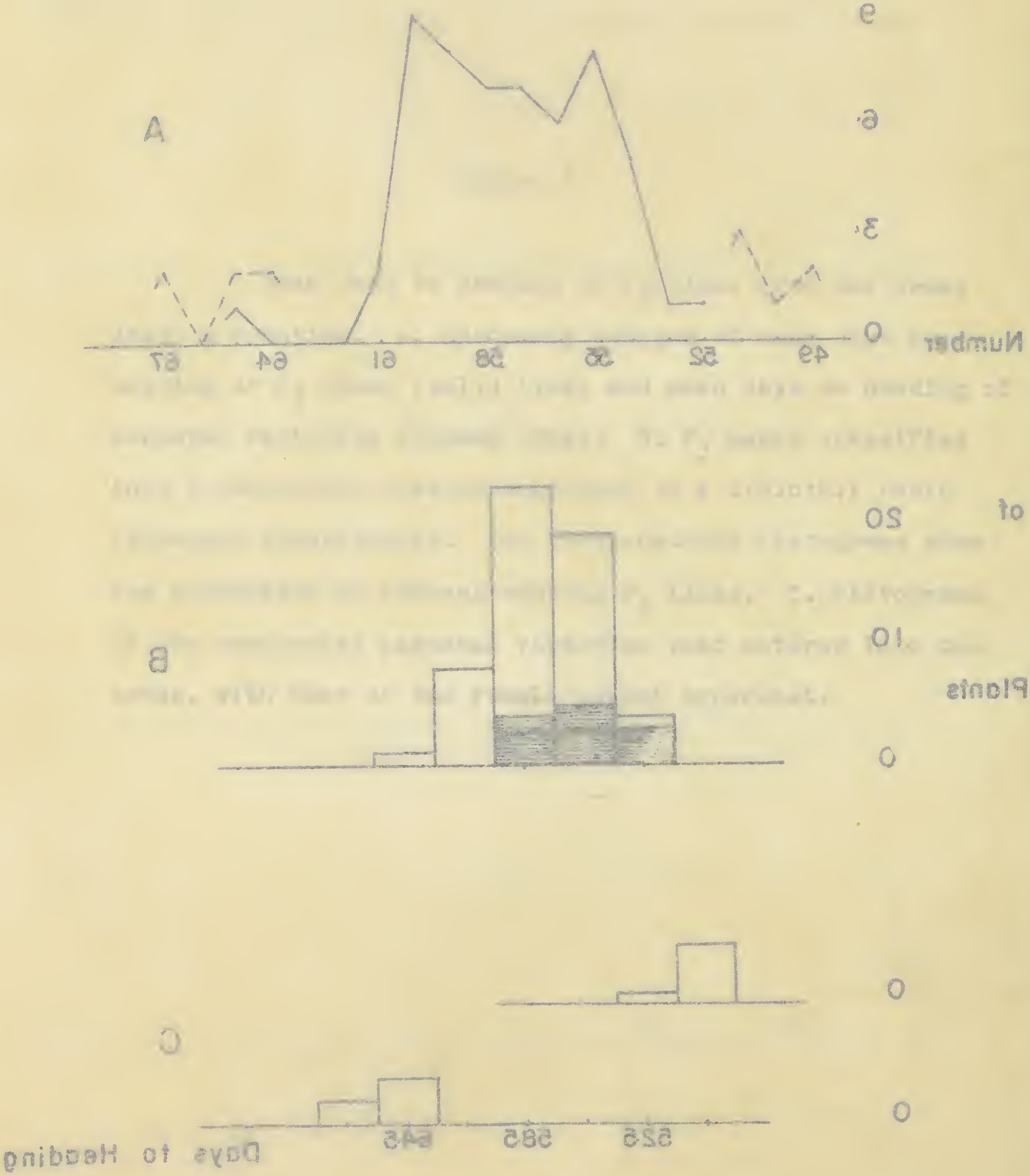

Fig. 3

Table XIVd

Frequency distribution of F_3 means (days to heading)

Montcalm x Atsel

D.T.H.	f	Class	X_c	f	f^1	f Montcalm	f Atsel
49	2	45.5	47.5	2	1		
50	2						5
51	3						1
52	7						
53	6	49.5	51.5	18	4		
54	9						
55	9						
56	6						
57	3	53.5	55.5	27	4		
58	1						
59	2						
60	1					2	
61	2		59.5	6	1	2	
62						2	
63							
64							
65		61.5	63.5	2[2]			
66							
67							
68	1						
69		65.5					
70	1						
	55			55	10	6	6

[1] Frequency of F_3 non-segregating lines.

[2] Classified arbitrarily into fifth phenotypic class.

Mean of F_3 means = 54.9

Chi-square for goodness of fit to 3:1 ratio = 8.855

p = 0.05 - 0.10

Figure 4

Mean days to heading of F_3 lines from the cross Montcalm x Atsel. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

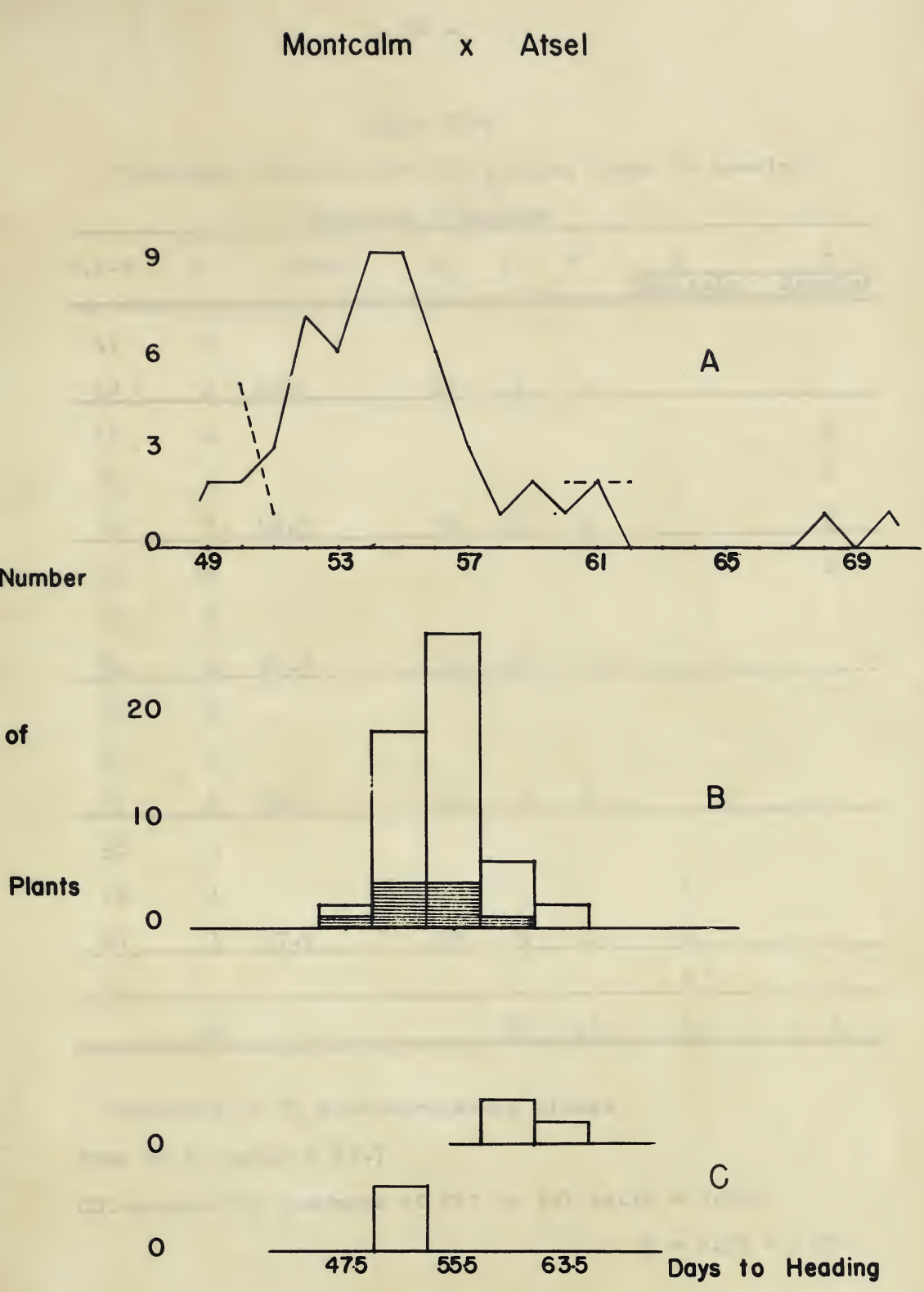
Montcalm x Atsel
9
6
3
0
A
49
53
57
61
65
69
Number
of
Plants
20
10
0
B
0
0
C
475
555
635
Days to Heading

Fig. 4

Montcalm x Atsel

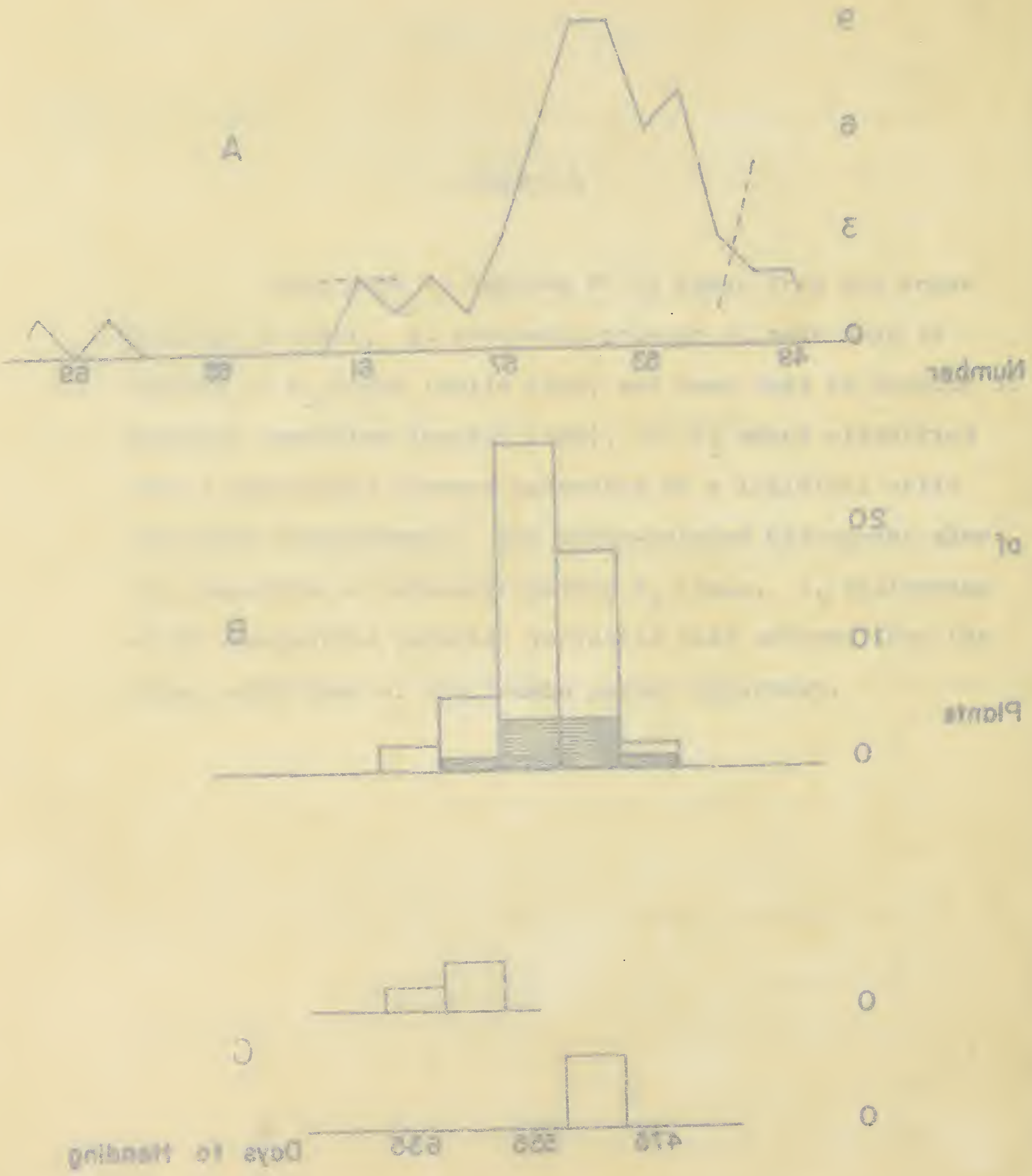

Fig 4

Table XIVe

Frequency distribution of F_3 means (days to heading)

Montcalm x Beecher

D.T.H.	f	Class	X_c	f	f^1	f Montcalm	f Beecher
47	2						
48	2	45.5	47	4	4		
49	4						1
50	4						2
51	7	48.5	50	15	4		2
52	12						1
53	6						
54	4	51.5	53	22	3		
55	4						
56	3						
57	2	54.5	56	9	6		
58	3						
59	1					1	
60	1	57.5	59	5	1	3	
61						2	
	55			55	18	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 52.7

Chi-square for goodness of fit to 3:1 ratio = 2.649

p = 0.50 - 0.70

Figure 5

Mean days to heading of the F_3 lines from the cross Montcalm x Beecher. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

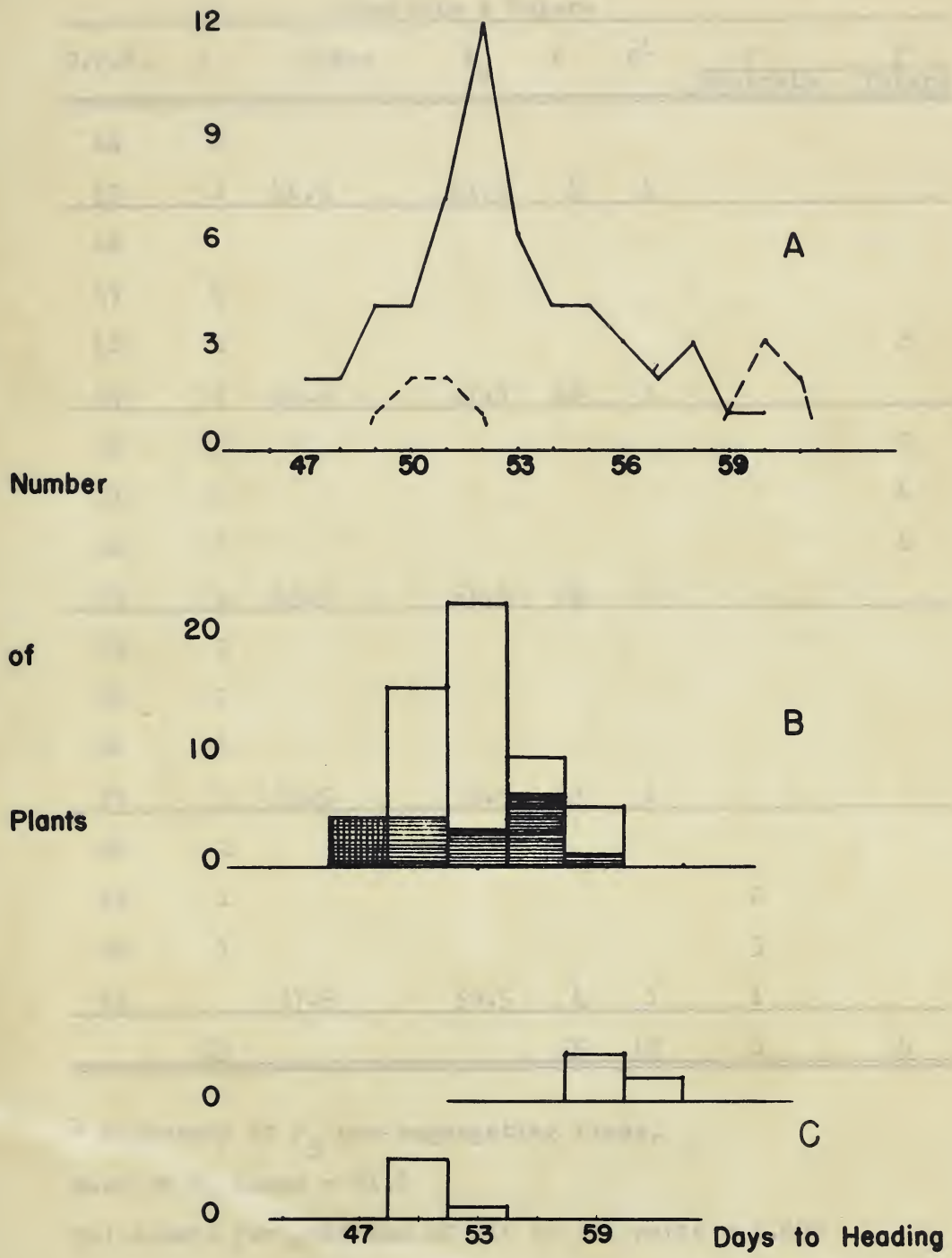
Montcalm x Beecher
12
9
6
3
0
A
Number
47
50
53
56
59
of
20
10
0
B
Plants
0
C
0
47
53
59
Days to Heading

Fig. 5

Montcalm x Beecher

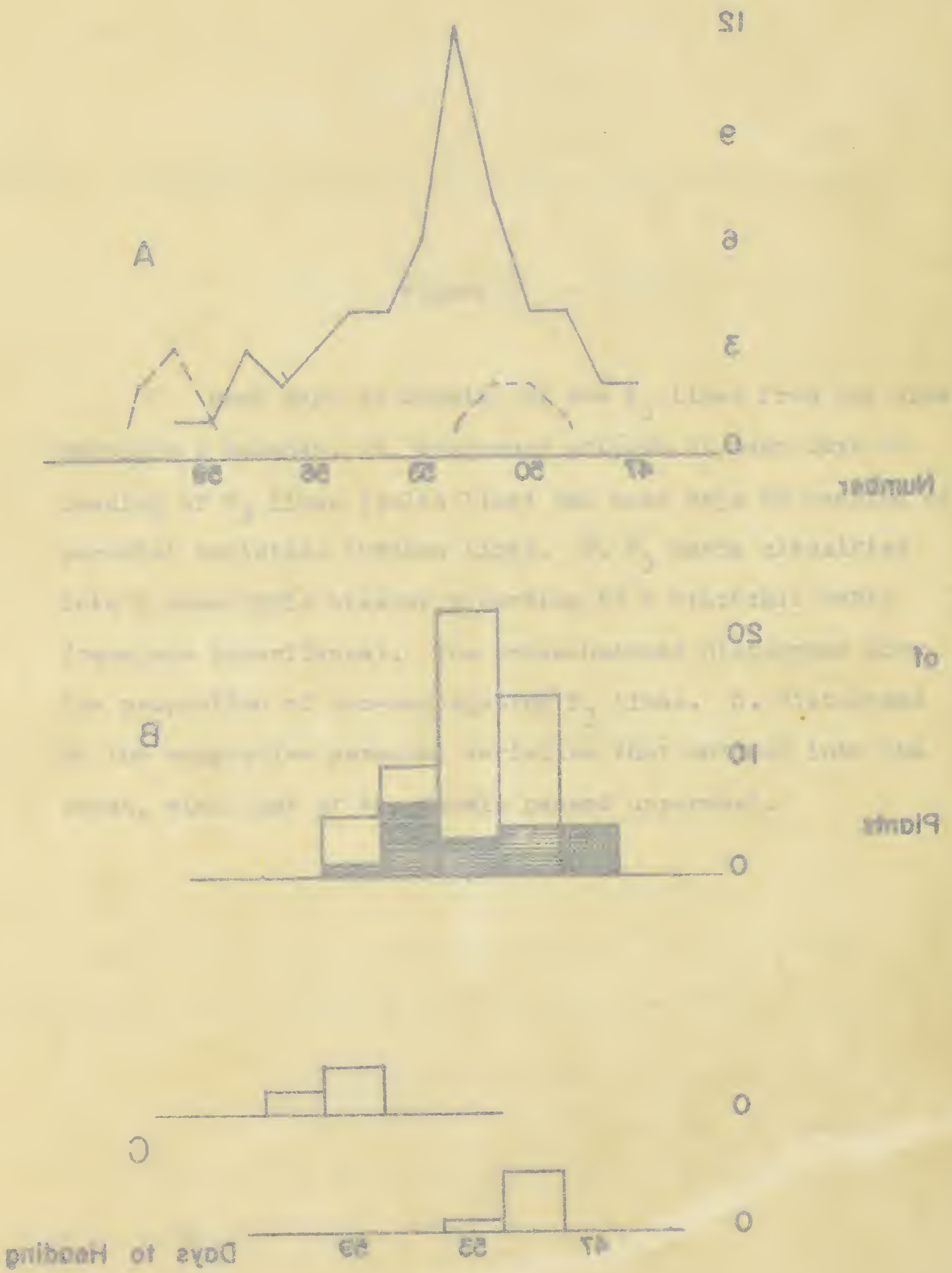

Fig. 5

Table XIVf

Frequency distribution of F_3 means (days to heading)

Montcalm x Tulare

D.T.H.	f	Class	X_c	f	f^1	f Montcalm	f Tulare
44	2						
45	2	41.5	43.5	4	4		
46							
47	4						
48	1						2
49	5	45.5	47.5	10	1		
50	10						2
51	4						1
52	6						1
53	4	49.5	51.5	24	5		
54	2						
55	2						
56	6						
57	3	53.5	55.5	13	1		
58	2						
59	1					2	
60	1					3	
61		57.5	59.5	4	1	1	
	55			55	12	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 51.8

Chi-square for goodness of fit to 3:1 ratio = 1.800

p = 0.70 - 0.80

Figure 6

Mean days to heading of F_3 lines from the cross Montcalm x Tulare. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

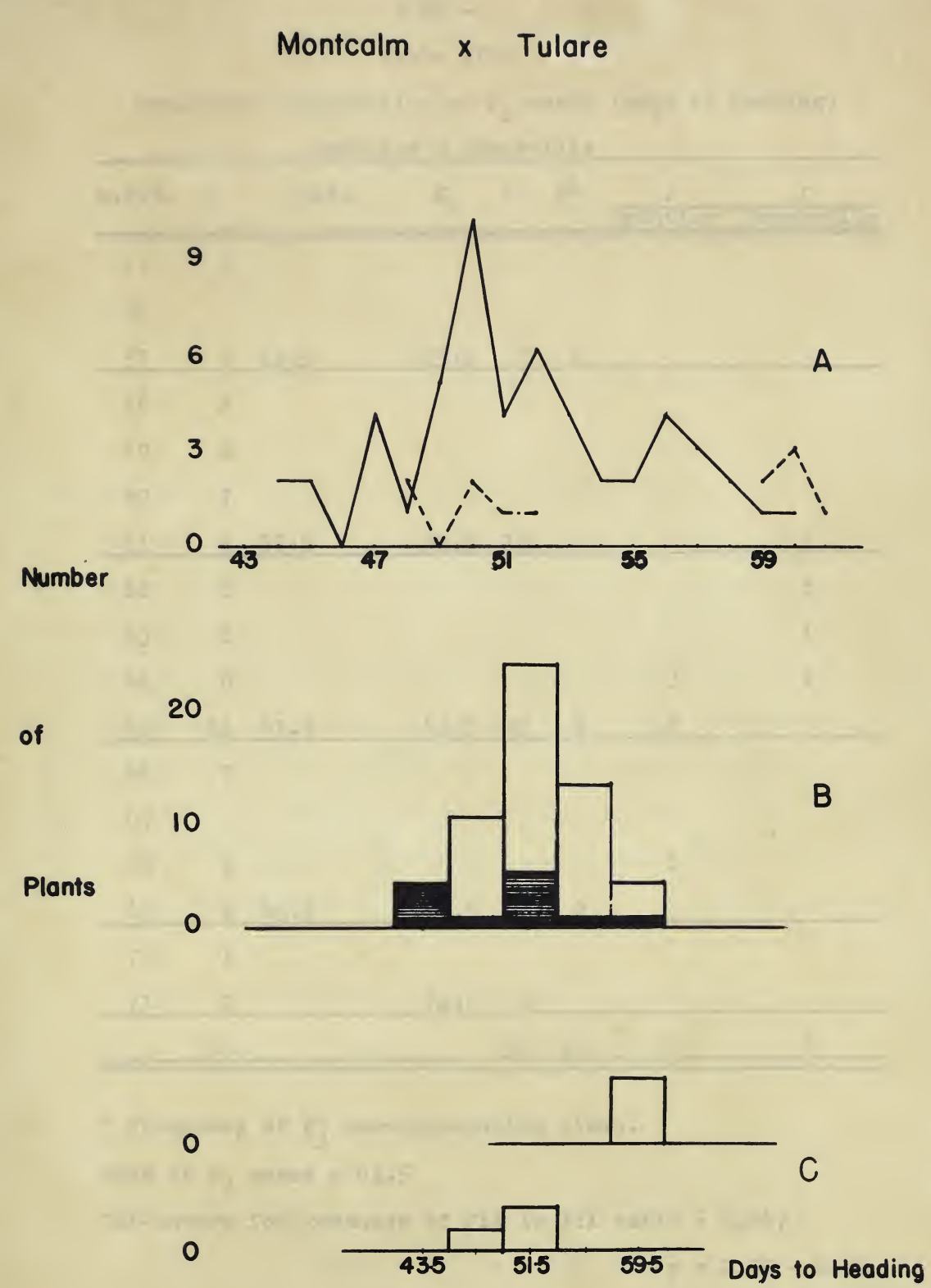
Montcalm x Tulare
9
6
3
0
A
Number
43
47
51
55
59
of
20
10
B
Plants
0
0
C
0
435
515
595
Days to Heading

Fig. 6

Montcalm x Tulare

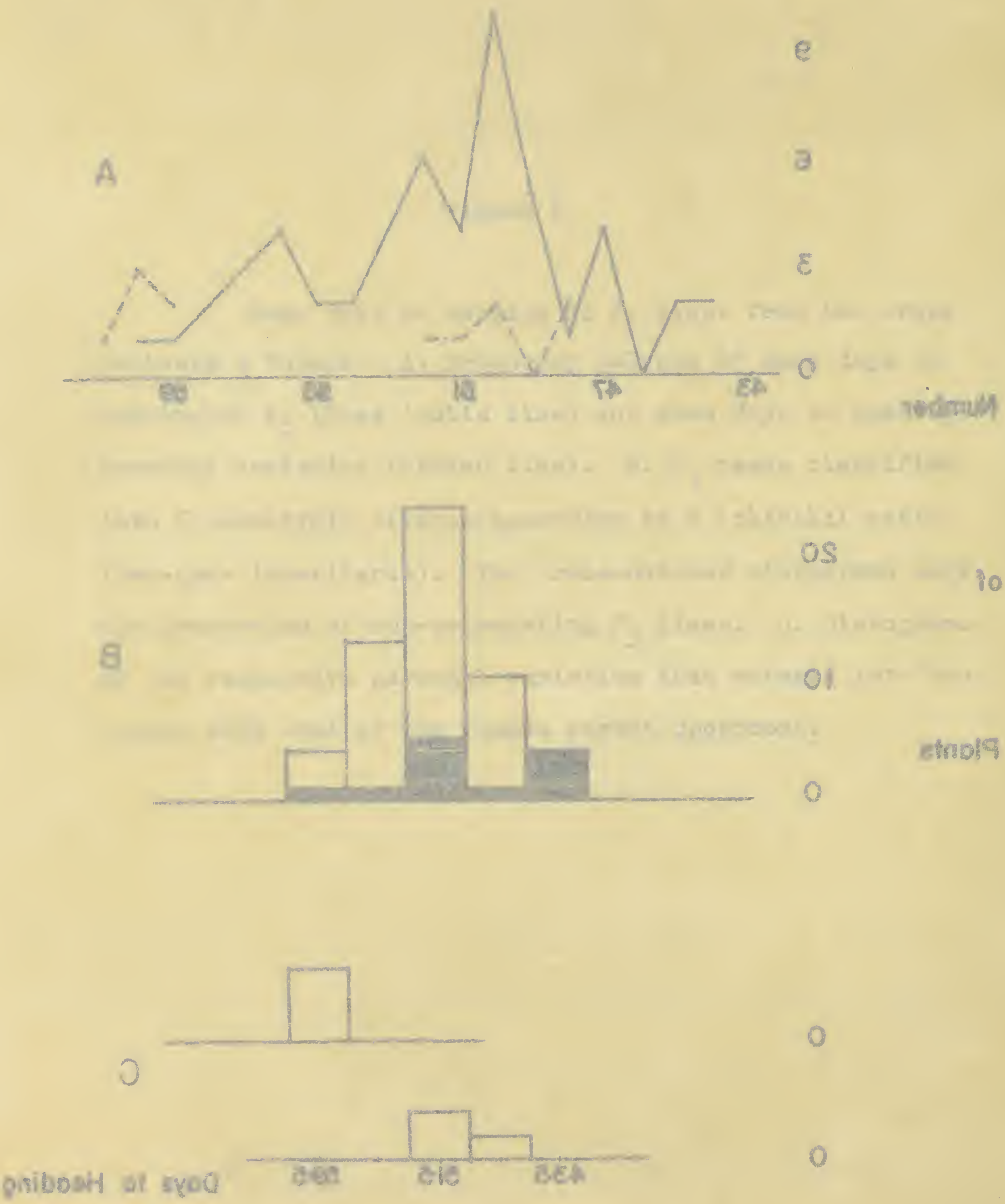

Fig. 6

Table XIVg

Frequency distribution of F_3 means (days to heading)

Frontier x Bonneville

D.T.H.	f	Class	X_c	f	f^1	f Frontier	f Bonneville
55	1						
56							
57	1	53.5	55.5	2	1		
58	3						
59	2						
60	7						
61	4	57.5	59.5	16			1
62	2						3
63	1						1
64	9					3	1
65	11	61.5	63.5	23	9	2	
66	7						
67							
68	4					1	
69	1	65.5	67.5	12	2		
70	1						
71	1		71.5	2			
	55			55	12	6	6

[1] Frequency of F_3 non-segregating lines.

Mean of F_3 means = 63.5

Chi-square for goodness of fit to 3:1 ratio = 2.067

$p = 0.50 - 0.70$

Figure 7

Mean days to heading of F_3 lines from the cross Frontier x Bonneville. A. Frequency polygon of mean days to heading of F_3 lines (solid line) and mean days to heading of parental varieties (broken line). B. F_3 means classified into 5 phenotypic classes according to a 1:4:6:4:1 ratio (two-gene inheritance). The cross-hatched histograms show the proportion of non-segregating F_3 lines. C. Histograms of the respective parental varieties that entered into the cross, with that of the female parent uppermost.

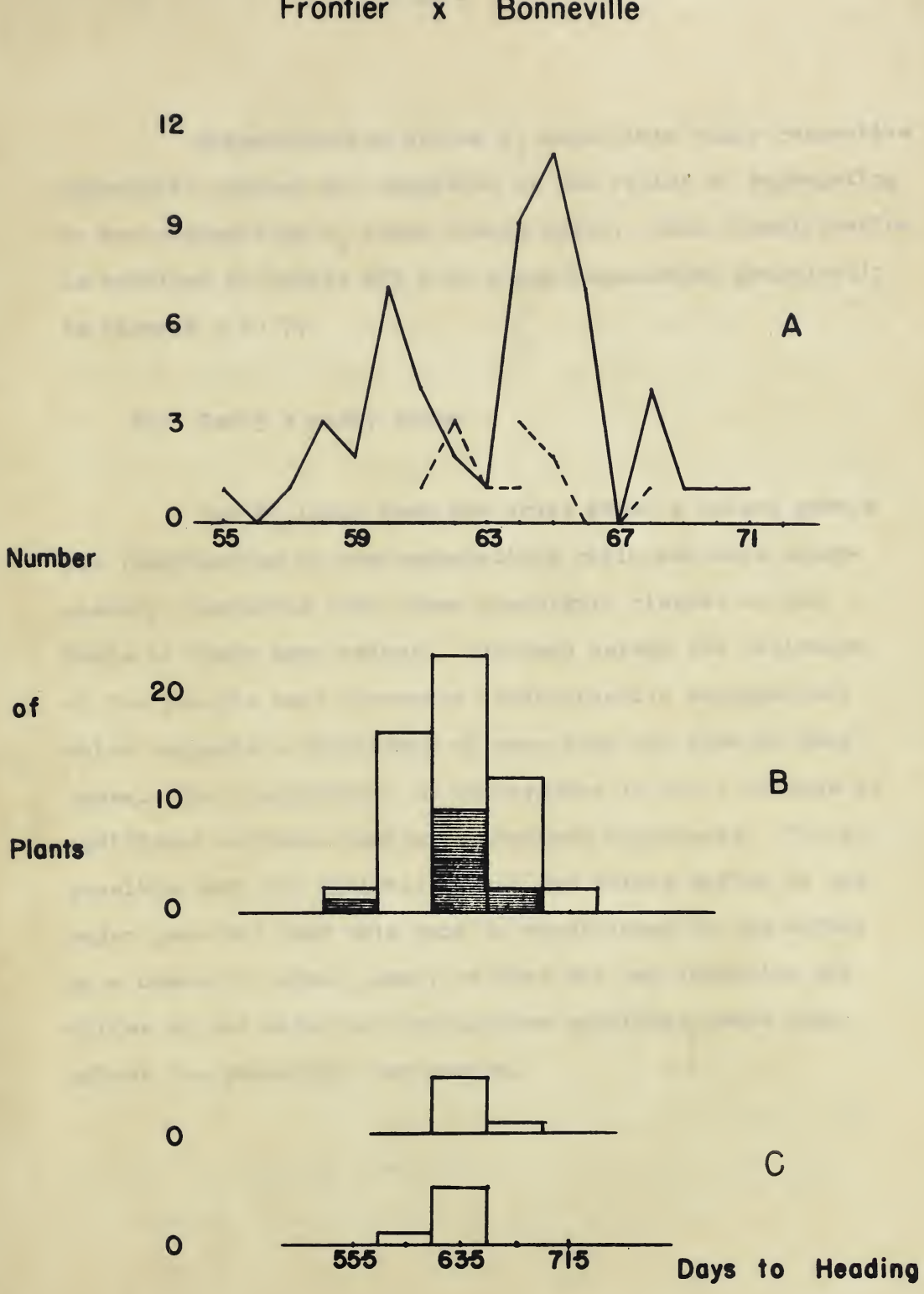
Frontier x Bonneville
12
9
6
3
0
A
55
59
63
67
71
Number
of
Plants
20
10
0
B
0
0
C
555
635
715
Days to Heading

Fig. 7

Frontier x Bonneville

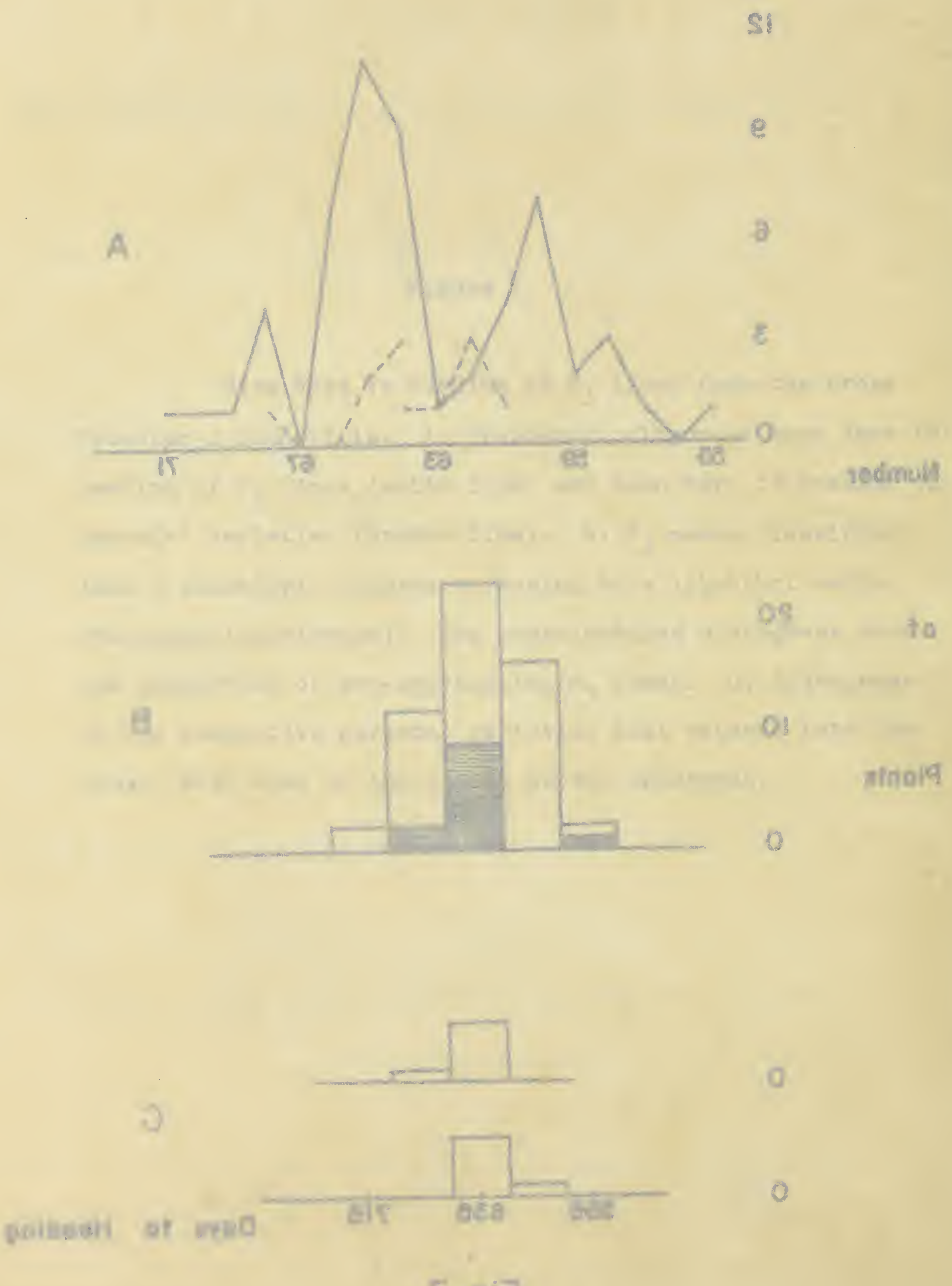

Fig. 7

Classification of the F_3 means into their respective phenotypic classes was suggested by the ratios of segregating to non-segregating F_3 lines (Table XIII). This classification is outlined in Tables XIV a to g and represented graphically in Figures 1 to 7.

(b) Early x early cross

The F_3 lines from the cross Atsel x Tulare gave a 1:1 (segregating to non-segregating) ratio and were consequently classified into three phenotypic classes on the basis of their mean values. Extremes beyond the variation of the parents were recovered (transgressive segregation) which suggests a difference of more than one gene in this cross. The distribution of homozygotes in the 3 classes is additional evidence against a one-gene hypothesis. It is possible that the varieties Atsel and Tulare differ in one major gene and that this gene is conditioned in its effect by a number of minor genes; or that the two varieties may differ at two major loci with minor modifying genes that affect the phenotypic expression.

(c) Early x late crosses

All crosses between early and late varieties gave evidence of incomplete and varying degrees of dominance. The reciprocal crosses, late x early, show evidence of transgressive segregation for earliness. This is not shown in the crosses between early x late varieties. The number of parental recoveries in each of these crosses (expected total = 7) is in agreement with the type of inheritance suggested by the ratios of segregating to non-segregating F_3 lines.

(d) Late x late cross

The cross Frontier x Bonneville shows pronounced transgressive segregation for both earliness and lateness. Although these varieties are similar in their date of maturity, the variety Bonneville has a winter barley in its line of ancestry which might explain the gene difference between these two varieties. The 3:1 ratio (segregating to non-segregating) suggests a two-gene difference, the similarity between dates of maturity suggests each variety having an equal number of increasing and decreasing allelomorphs and, finally, transgressive segregation places the increasing allelomorphs in each variety at different loci.

The distribution of homozygotes in the phenotypic classes varies with each cross; that of Atsel x Tulare is perhaps the poorest and that of Montcalm x Tulare the best distribution. The means of lines with the genotype AABBCC or aabbcc are relatively more stable than the means of lines with the genotype AaBBCC or AABbCC, (segregation at one locus) which in turn are more stable than the means of F_3 lines that show segregation at two loci. With this idea in mind it is realized that the classification based on means is perhaps too rigid, and that means falling on the class borders should be assessed taking their relative stabilities into consideration.

CONCLUSIONS

The method of determining the mode of inheritance in barley used in this study can at best determine only the number of gene differences between the two varieties that entered into the cross. With a knowledge of the origins of the varieties it is reasonable to suppose that varieties with a similar phenotype may have genes for earliness each at different loci. Although plants within a variety, on the basis of their true breeding behaviour, are alike in genotype for major genes, they may very well differ in varying degrees for minor genes, dominance, and epistasis. The best estimate of the gene difference is the average number of genes in which the two varieties differ.

The most definite conclusion that may be drawn is that the parental varieties studied differ at two loci. The genes involved in six of the crosses appear to be equal in effect, while in one, Atsel x Tulare, they may vary in effectiveness. Minor genes, modifying genes and growth or vigour genes may modify the effects of the major genes.

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